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A Computer Program (VEHSIM) for Vehicle Fuel Economy and Performance Simulation (Automobiles and Light Trucks)

Volume II: Users Guide

DEPARTMENT OF
TRANSPORTATION
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October 1981
Final Report

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16. Abstract

This report presents an updated description of a vehicle simulation program, VEHSIM, which can determine the fuel economy and performance of a specified vehicle over a defined route as it executes a given driving schedule. Vehicle input accommodated by VEHSIM include accessories, engine, rear axle, converter transmission, tires, aerodynamic drag coefficient, and shift logic. The report is comprised of four volumes. Volume I presents a description of the numerical approach and equations, Volume II is a user's manual, Volume III contains the program listings and Volume IV describes a simulation of the Integrated Overdrive Transmission with a split-torque converter.

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PREFACE

Volume II is a continuation of a multi document set describing VEHSIM. This volume contains sample simulations, an explanation of the input data and input forms, graphical options program for use with VEHSIM and a list of common errors for the beginning VEHSIM user.

A strong effort has been made to consider the user's viewpoint from the execution of the program. Sample cases have been included to illustrate the various simulation methods available and the most frequently used VEHSIM options.

The Energy Technology Branch expresses thanks to Mr. Jack Dolan, Systems Development Corporation, for assisting in the preparation of this volume.

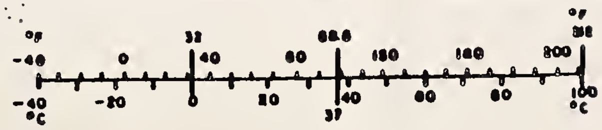
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

This manual will describe the VEHSIM operating commands and the various methods in which the user can execute the program. For each method of operation, interactive, batch processing from a terminal and batch processing using a card deck, a sample run will be presented along with a listing of the input data format and the sample output data.

The method of operation chosen by the user, at a particular time, will probably be the one most convenient. For example, interactive operation typically requires more connect time at a terminal than batch processing, but offers the advantage of maximum convenience when modifying the components of the vehicle in order to determine the influences on fuel economy. Batch processing requires a VEHSIM control file (made up of VEHSIM operating commands and parts) which must be created before submitting the run, but offers the advantage of executing the program during low rate, off-peak hours. The use of cards, rather than a terminal, may be more convenient for preparing a VEHSIM control file due to the enumerated column headings, especially for a user not accustomed to terminal operation. Submitting cards for execution of VEHSIM usually becomes unnecessarily cumbersome once a VEHSIM control file has been prepared in the user's disk area. Once a VEHSIM control file has been prepared, it will be most convenient for the user to submit it from the terminal.

The program is most efficient when a large scenario is being executed in such a way as to optimize data retrieval from the disk. For example, a series of *USE commands could be used to "construct" the vehicle initially. Then, a sequence of alternating *MODIFY and *SIMULATE commands would allow the user to try different vehicle weights with different rear axle ratios. This would require no further disk accesses and would accomplish many trials. At that point, a different drive schedule could be retrieved from the disk and the process could be repeated for more trials. If, the user alternated drive schedules for each *MODIFY command, the program would use a great deal more time to retrieve data from the disk and, therefore, cost more to run.

VEHSIM was designed to operate on the Control Data Corporation 6600 Scope Operating System using the Run 2, 3 Fortran Compiler. However, VEHSIM is programmed in the Standard FORTRAN IV language and should convert to other systems readily with only minor modifications to system dependent operations. For the contents of this particular manual, any and all references made to the loading, execution, etc., of the VEHSIM program, will pertain to the in-house DEC system-10 Timesharing System.

2. PROGRAM EXECUTION

2.1 SIMULATION COMMAND STRUCTURE

Since VEHSIM is designed to function by a series of commands input by the user, the user should be familiar with each command, its special purpose, and its use. These commands may indicate new data to be stored on the disk file, old data to be retrieved from the disk file, modifications to data currently in core, etc. All VEHSIM commands are identified by an asterisk (*) in column one (1), followed by the command directive, if any, to complete the command. VEHSIM commands, for both interactive and non-interactive operation, will be listed and described in this section. Some commands have a common name and produce the same result for interactive and non-interactive operation.

The following is a list of commands which are available for the VEHSIM model. As explained previously, the VEHSIM commands have a general purpose or function, i.e., storing new parts on the disk, retrieving parts currently residing on the disk, etc., and that is the context by which these commands will be presented. All VEHSIM commands contain a unique part name beginning in Column 19. The actual format of the command is shown in detail in section 3.

Storing New Parts Data

*ENGINE - indicates that engine data is to follow

*FULL CONVERTER - indicates that torque converter data is to follow specifying input and output torques and RPM's

*S.R. CONVERTER - indicates that torque converter data is to follow specifying input torque and RPM along with a speed ratio and torque ratio

*VEHICLE - indicates that gross vehicle data (weight, frontal area, axle ratio, etc) is to follow

*GEAR - indicates that data for a single gear is to follow

*SHIFT LOGIC - indicates that the shift criteria (shift lines, shift time, etc) is to follow for all the gears in the transmission

*ACCESSORY - indicates that data for an engine accessory (fan, air conditioner, etc) is to follow

*DRIVING SCHEDULE - indicates that data, in segment form, describing the particular driving schedule (segment number, acceleration, speed, time, etc) is to follow

*ROUTE - indicates that data describing the physical route (distance, grade, etc) to be driven is to follow; the grade and road coefficient specifications are from the last, up to the current data point milepost.

If a part is to be input using the same unique name as a part already stored in the disk data file, the request to store this part on the disk will be ignored.

Retrieving Parts Data

*USE - This command allows the user to retrieve data already stored on the disk data file. The unique part name followed along with the choice of part data being retrieved. The part type begins in Column 19. The valid part type choices are:

ACCESSORY
CONVERTER
DRIVING SCHEDULE
ENGINE
GEAR
ROUTE
SHIFT LOGIC
VEHICLE

The unique part name which begins in Column 7, is the same name assigned to that particular part when it was stored on the disk data file as a new part. When the *ENGINE comand is specified, the user must define to which engine number and to which gears the engine data will be assigned. For *ENGINE, the program allows a maximum of 20 gears and 2 engines. If the *GEAR command is specified, the user must give the gear number to which this data is to be assigned. Up to 20 accessories may be included by using the *ACCESSORY command.

*REMAP - This command allows the user to obtain an engine map, engine data, which will print out the speed and torque points that the user specifies rather than the points as input initially. This capability provides a convenient method of comparing fuel rates, vacuums, etc., between engines whose initial data were taken at different points in the engine performance map. Again, the unique name of the engine to be remapped should begin in Column 19. The units for engine speed, torque and fuel rate must be specified as follows:

(a) RPM - engine speed (RPM)
(or) PISTON piston speed (ft./min.)

(b) TORQUE - torque (lb.-ft.)
(or) BMEP - brake mean effective pressure (psi)
HP - horsepower (hp.)

(c) LB/HR - fuel consumption (lb./hr.)
(or) BSFC - brake specific fuel consumption (lb./hp.-hr.)
(or) GAL/HR - fuel flow rate (gal./hr.)

*DUMP - This command allows the user to obtain a dump of a particular part or of all the parts currently stored on parts data file. If the word

DIRECTORY appears, beginning in Column 19, instead of a part name, only the names and comment fields of the various parts will appear in a directory format.

Modifying The Parts Data

*MODIFY - This command enables the user to reset the value of a number of individual program parameters without creating a change in those parameters in the original data set on the disk file. The MODIFY command should only be used after the USE command which retrieves the data to be overridden. Available option names, which also begin in Column 19, are as follows:

AREA - frontal area (sq, ft)

C1 - first constant in rolling resistance equation (dimensionless)

C2 - second constant in rolling resistance equation (1./MPH)

CD - aerodynamic drag coefficient

CYLINDERS - number of cylinders in the engine

DIESEL - fuel shut off during deceleration

DISPL - engine displacement (cu. in.)

DOWNSHIFT - % change in vacuum/throttle downshift level

DYNAM - dynamometer (HP)

FUEL - fuel specific gravity

IDLE - engine idle (RPM)

LOCKUP - an RPM for a particular gear

REAR - rear axle ratio

STEP - time step for the program (sec.)

STROKE - piston stroke (in.)

TIRE - tire efficiency (≤1.)

WEIGHT - gross vehicle weight (lbs.)

WIND - wind velocity (MPH)

UPSHIFT - % change in vacuum/throttle upshift level

The default time step of 0.05 seconds may be overridden with the MODIFY command to perform the same run with a longer time step in order to cut cost. [Note: Due to certain tolerences built into the program, a time step of less than 0.05 seconds is not recommended. Also, if a new stroke, number of cylinders or displacement is specified, the program will automatically scale the engine(s) prior to the start of the next simulations.]

*LOCKUP CONVERTER GEAR
*UNLOCK CONVERTER GEAR - These commands provide the user with the capability of "locking up" or "unlocking" the torque converter for any of the gears in a particular transmission. LOCKUP will render the torque converter invisible by setting the speed ratio and the torque ratio to unity and zeroing the input and output inertias while the vehicle is in the specified gear(s). UNLOCK can be used to "unlock" a previously "locked up" gear. When an automatic transmission is being used, the gears will be "unlocked" and when a manual transmission is used, the gears will be "locked up."

*PRINT UNITS(S) - This command allows the user to specify units for the engine data printout resulting from a USE or ENGINE command into units other than those in which it was originally input on the disk data file. The units are the same as those described in the REMAP command section.

*ZERO - This command allows the user to zero the core memory containing all data currently stored by the program and reset all program flags and pointers. In the case of accessory data, for example, the program accumulates a list of accessory tables, one for each USE command. Unless a ZERO command is issued, a new set of accessories would be added to the old set rather than their being replaced.

Performing and Monitoring a Simulation

*SIMULATE - This command begins the actual simulation. It first checks to see that all of the necessary parts have been assembled from the parts data files on the disk by means of the USE commands or new parts data cards and allows the vehicle to reach the initial conditions specified by the driving schedule and then, executes the actual driving schedule itself. At the end of the simulation, more USE or MODIFY commands may be used to bring in or reset data for another simulation, and so forth, until the end of the input data is reached at which time the program terminates execution.

*LIMIT PRINT - This command enables the user to limit the amount of printed output that is to be received for the simulations that have been requested. The four available options are:

SEGMENT - prints out detailed output for the final time step of each segment of the driving schedule as well as the initial conditions step.

MILE - prints out detailed output at fixed mileposts along the driving schedule (e.g. every 0.1 mile) as well as the initial conditions steps.

SEC - prints out detailed output at fixed increments along the driving schedule (e.g. every 10.0 seconds) as well as the initial conditions step.

OFF - prints out detailed output at each and every time step in the simulation.

SUMMARY - only the summary sheet is printed at the end of the simulation

(Note: Unless otherwise specified, the program defaults to SUMMARY. If OFF is given, the printout includes the parts data accessed by a USE command; otherwise, no parts data will be listed.)

*TITLE - This command allows the user to specify a 60-character title which will appear on the top of the summary data page at the end of each simulation. Each TITLE command overrides the previous one so that the user has the option of specifying a different title for each simulation or the same title for all of the simulations performed during that run. The data to be printed on all outputs may be specified here to override the actual data.

*DELETE }
*DROP } - This command will cause the part named to be dropped from the parts data file. Its format and choices are the same as the USE command except no engine or gear numbers are specified.

*DEBUG - This command can be used to give the user extra information beyond the regular run printout. It is very useful for debugging runs that fail or runs that appear to have a problem (e.g. irregular shift patterns). The DEBUG command can be operated in four modes:

OFF - turns off DEBUG printout entirely

SHIFT prints DEBUG information before and after each shift from the 'start' to the 'stop' segments. Also, this command is useful for detecting shift stutter.

SEGMENT - prints DEBUG information from the 'start' to the 'stop' segments.

(Note: The DEBUG mode will remain in effect until it is changed by another DEBUG command. This command is optional and the default value is OFF.

In the IA mode, DEBUG is activated by typing "DEBUG" (cr). VEHSIM will type "DEBUG": indicating that it is in DEBUG mode. Then enter the mode and start and stop limits. This line is read using a format of A5,2F so one must be sure to enter enough spaces between the mode and the start limit. DEBUG output format comes in four lines containing the following variables:

line 1 CUMT, CUMD, V, ACCEL, FWHEEL, FROLL, FAERO, FACCEL, FGRADE;

line 2 DT, NGEAR, ISEG, NRTSEG, TORQW, TR, TORQP, TORQ2, TORQ1, TORQF, TORQE;

line 3 PCTWOT, HIDNAM, HPBR, RPMW, DRPMW, RPMP, RPM2, RPME, DRPME;

line 4 NGOCAL, MAPOK.

These variables are defined in Volume III. If no "start" limit is given, DEBUG will start at the start of the simulation. If no "stop" limit is given, DEBUG will continue until the simulation ends or aborts. DEBUG mode will remain in effect for all SIMULATE commands until it is changed to another DEBUG command. The default value is off. The user is cautioned against using DEBUG, since voluminous printout may result. The shift DEBUG output format is printed in the following order:

HSMODE, HTMODE, CUMTLS, CSTIM, TORQA, TORQAO, ATORQF, ARPME, DRPM1E, DRPMC, DTC, LCLTCH.

This data is printed only during shifting.

A special note on the command:

*SPLIT	- As an enhancement to the model, this command is used to trigger a flag indicating a split torque converter is being used. No other keyword or words are necessary with this command. Since this command cannot be changed with the MODIFY command, it is suggested that if the user is simulating more than one case and the SPLIT command is being used, then the SPLIT command should be at the beginning of the last case.

2.2 GENERAL USER INFORMATION

Before proceeding to the actual execution of the model the user should be aware that the overall method to be followed in using VEHSIM is to 'construct' a vehicle by retrieving data currently on the disk files, modifying the data, if necessary, and then, executing the desired driving schedule.

The minimum amount of data required for any given simulation is as follows:

1) engine data
2) vehicle data
3) torque converter data (one table for the drive converter and one table for the coast converter)
4) gear box data
5) a shift logic
6) a route description
7) a driving schedule

Optional data consists of accessory tables which are not required, but may be included, if desired. As mentioned earlier in the command section, when a manual transmission is required, the user may specify that all gears are "locked up." This means that the speed ratio and the torque ratio, for the torque converter, will be set to unity. In addition, an appropriate shift logic should be used.

2.3 LOADING THE PROGRAM

The fact was mentioned in the Introduction, but the reader is reminded, that, "...any and all references made to the loading, execution, etc., of the VEHSIM program, will pertain to the in-house DEC system-10 Timesharing System." Being aware of this will facilitate the effort and hasten the time required to get the VEHSIM model operational. Also, when examples of simulations are listed, in the interactive and particularly indirect modes all user responses will be underlined.

When the user issues the LOAD command, the Linking Loader, LINK-10, is automatically initialized. The main input for the LOAD command is the Fortran program for the VEHSIM model and the associated assembly language program. Output of the LOAD command will be an executable version of the user's programs, an object module, that will be in the form of a binary file. Since the loaded program at this point reflects the state of the user's core memory, it is usually referred to as the core image.

Since the LOAD command is part of the COMPIL-class commands, compilation of the subroutines takes place. FORTRAN-10 responds with two levels of messages - fatal error and warnings. Warning messages indicate a possible problem. The compilation will continue and an object program will be generated. If a fatal error is encountered in any pass of the compiler, the remaining passes will not be called. Additional errors that would be detected in later compiler passes may not become apparent until the first errors are corrected. As the word fatal denotes, it is not possible to penerate a correct object program from a source program which contains a fatal error. The format of the messages is:

```
?FTNXXX LINE:  n text
         or
%FTNXXX LINE:  n text
```

where

? = fatal
% = warning
FTN = FORTRAN mnemonic
XXX = 3 letter mnemonic for the error message
LINE: n = line number where error accurred
text = explanation of error.

This feature will be fully appreciated by the user, when a new core image file is being created; consequently the user may find it desirable to retain the former core image, because of an enhancement to the program, finding an error in the program, etc.

Now that the LOAD command has been completed and a core image file is ready, the user can request LINK-10 to output the core image to the user's area for storage. By using the SSAV command along with an appropriate name for the model, the user avoids future loadings of the model. The program is now ready for execution when the user enters the RUN command along with the name entered with the SSAV command.

If space on the user's disk area is at a premium because of other programs or data files, the user may delete the REL file generated by the LOAD command after the SSAV command has been completed.

As a final note, the switches in the LOAD string effectively reduce the swapping time of the system especially if two users happen to be using VEHSIM at the same time.

2.4 EXECUTION

A description of VEHSIM execution, through interactive and non-interactive operational modes, will be provided in this section.

The interactive mode permits the user three possible simulation methods:

1) interactive simulation in which the user is queried or directs VEHSIM
2) attached simulation through execution of a VEHSIM control file with monitoring at the terminal
3) detatched simulation through submission of a batch control file.

The first two methods permit switching control from one method to the other after completion of each run.

The non-interactive mode permits the submission of punched card batch control files. The card deck will contain a VEHSIM control file and instructions to execute VEHSIM. This method functions in a manner similar to detached simulation, except for the use of cards instead of interactive terminal commands.

In both the interactive and non-interactive modes it is assumed that the VEHSIM program and the required parts to be accessed are already on the disk. The interactive operational mode will be referred to as IA and the non-interactive mode will be referred to as NIA. During simulation in the IA mode, commands are typed on the terminal, whereas in the NIA mode, commands are punched on cards with an asterisk, starting in the first column. In the following descriptions, the abbreviation (cr) and the arrow (↲) both will indicate a carriage return in the IA mode. All of the NIA mode command formats are specified exactly by the data format sheets; therefore, these descriptions will not be repeated here.

2.4.1 Interactive Simulation

The ASK command puts VEHSIM into the IA mode. When using the ASK command, VEHSIM will cycle through all of the part types, querying the user as to the unique name of the particular part being used. When all of the parts have been loaded, VEHSIM gives the user the option of going directly to the simulation or not, or going into the DIALOGUE mode, by asking "SIMULATE (Y/N/D)." If the user elects not to simulate, N, VEHSIM will then ask if various modifications are desired. When all of the modifications are completed to the user's satisfaction, the user is again offered the choice "SIMULATE (Y/N/D)." The user may cycle through the parts and modifications until the simulations are as he wishes. Then, the user may start the simulation, Y, or go into the DIALOGUE mode, D.

For interactive simulation, a number of characters have been designated to perform a few key functions through a program interrupt. These characters will also apply to the indirect simulation. These characters are as follows:

CTRL D - Type out debug information

CTRL E - Close all files and exit to monitor

CTRL N - Suppress end of driving segment messages

CTRL P - Pause to modify then continue simulation

CTRL S - Type out current status of simulation

CTRL D - Turn off simulation output except for error messages.

The CTRL abbreviation indicates that the teletype terminal control key is to be depressed. The first time that the special character is engaged, its function begins; if and when it's pressed again, the original condition returns. For example, when the CTRL N character is pressed, the end of driving segment messages are suppressed. However, if the user decides that he wants to know how far into the driving schedule the simulation has gone, another CTRL N will resume the end of driving segment messages.

While in the interactive mode, parts data may be listed for a particular part, all the parts within a part type, on the entire parts file. A listing is accomplished through the DUMP command which queries the user about the part and where it is to be printed. Wild characters or a carriage return may be used as required for a group of parts.

The user has an option to obtain a directory of an individual part to make sure it currently resides on the disk, or a directory of all the parts within a part type, or for all the data currently stored in the disk parts data file. The directory command, DIR, is used for this feature along with a carriage return or wild characters for maximum flexibility. If the user wants a directory typed directly at his terminal, the TTY command must be entered. The directory which comes to the user's terminal is a "fast" directory, that is, only the part name will be typed. The print file directory (which automatically is printed during the DIRECTORY command) gives a "full" directory, that is, the part name, protection, data created, the part creator's identification code and the comment field associated with each part, are all included.

An interactive simulation does not produce a LOG file since the terminal output is a printed copy. A VEHSIM data file is generated which the user may SAVE, PRINT or DELETE after a run.

2.4.2 Indirect Simulation

Use of the INDIRECT (@) command allows the user to enter VEHSIM commands from a pre-made VEHSIM control file on the disk. Some users feel that the indirect simulation of VEHSIM is very convenient because once a control file is made, a minimum amount of user interaction is required. The command is used in the following manner:

```
@DEV:FILE EXT[P,PN]  (cr)
    or
@FILE, EXT ↵
```

where DEV:FILE.EXT[P,PN] is the general form for the control file input.

The VEHSIM program will then ask the user if a printed copy of the data file is desired. The user may save, print or delete the data file being used. The program will now automatically check the user's commands and the parts until the last command of the initial simulation is encountered; at this point, the program will switch control back to the user. The user will know when command has been switched because an asterisk (*) will appear on the teletype. Since everything appears to be correct, the user may begin the simulation by typing SIM with a carriage return immediately following the asterisk. The program will now let the user know that the simulation is starting and has reached its initial conditions. Next, the program will print a message at the end of each driving schedule segment, unless the user has used the CTRL N interrupt, when, after the driving schedule has been completed, the summary data sheet will be printed. The program will again return control to the user by printing an asterisk. Here, the user may choose to end the simulation by entering the word EXIT (cr) or continue the simulation, if more cases are involved, by entering CONT (cr).

When the user has finally decided to terminate the simulation, he has the option of deleting, saving or printing (most probably) the data at the indicated time step of the simulation. The user can now enter D, DELETE, S, SAVE, P or PRINT, and the program will now end its execution in the indirect mode.

2.4.3 Batch Simulation

2.4.3.1 Attached Simulation - A simulation can be conducted by the user at the terminal by entering a VEHSIM control file through the use of the BATCH command. Just as in the indirect mode of simulation, the program will cycle through the list of parts until the SIMULATE command, with the DIALOGUE option, returns control to the user. Here, before starting the first simulation, the user can make any desired modifications. Then, by typing SIM or SIMULATE, the user starts the first case. At the end of each case or simulation, after the summary sheet is printed, the user may exit from VEHSIM, EXIT, continue with the next case, CONTINUE, or change modes, DIALOGUE.

2.4.3.2 Detached Simulation - Basically, the batch control file is a series of instructions which tells the VEHSIM program which file in the user's area will be the input file.

Output from a batch job is written directly to a line printer. Along with the regular simulation output, a program - created log file is produced. It is useful to print the log file especially if an abnormal condition terminates the run. At the completion of the run, the log file will be automatically retained in the user's area.

The print options previously described for interactive operations may also be used in batch processing.

2.4.3.3 Batch Card File Submission - Using a card deck input to run VEHSIM assumes that the program is already available on the disk. The card deck essentially contains a VEHSIM control file which serves as input data to run VEHSIM. The program is controlled in a manner similar to a terminal batch job, except for the use of cards.

2.5 OUTPUT

The LOG File

An interactive simulation does not produce a Log file since the terminal output is the printed copy. However, the interactive mode does produce the default output which includes the segment number of the driving schedule, segment time, distance, speed, CPU time in the segment, and the total CPU time. Also, five different clusters of data used in the simulation are printed in summary fashion at the end of each individual case.

Since the clusters of data have been mentioned, a brief word should be said about each cluster.

The first cluster shows the fuel economy, engine work per mile, average brake specific fuel consumption and average speed. If an emissions simulation were being performed, the fuel economy would show the reciprocal of the emissions (NOx or NOX simulations are reasonable, HC and CO are not recommended) in grams per mile, provided the specific gravity in the engine map is specified as 0.1198.

The second cluster contains additional run data, the vehicle specification, and run conditions. With the exception of the aerodynamic drag and tires, this cluster is self-explanatory. The aerodynamic drag information shows the cross-sectional area and drag coefficient, while the tire information lists the linear term of the rolling resistance equation (lb/1000 lb), the velocity dependent term (lb/1000 lb per MPH), and the tire friction (slippage) factor expressed as a decimal percentage.

The third cluster shows the time, distance, engine energy, and fuel. The percent of each total is portioned into amounts used during cruise, acceleration, deceleration, and idle. The fuel used during the braking is the percentage of the total which is consumed during closed throttle deceleration.

The fourth cluster of data shows the breakdown of the energy being supplied to the vehicle. Potential and kinetic energies and rotating inertia will be shown for certain types of driving schedules such as simulating the vehicle going up a hill (grade) and then terminating the driving schedule at the top of the hill.

The fifth cluster lists the percent of engine work consumed by various losses, the amount of engine braking and engine monitoring. Each of the losses is broken out separately, which provides the user with a convenient method to assess the influence of improved components. The percentage total should be approximately one hundred (100); however, this total will vary according to driving schedules and vehicles. The total is due to the numerical methods being employed by the model and transient effects. This total is not to be taken as an indication of the accuracy of the simulation.

In the batch simulation, a dump of each part used, a status report (names of the parts used), the output of the simulation at each specified time, shift frequency, the five cluster summary, and a summary of the breakdown of the percent of time spent on various parts of the engine are made. The LOG file is automatically printed and stored in the user's area.

2.6 VEHSIM PARTS GENERATION

Normally, the user will not have to generate parts and add them to the data base. However, the user may want to generate new parts, create new situations (routes, driving schedules), and analyze the effects upon the model.

Generate Parts File

The parts which can be loaded correspond, to the parts data described on the input forms. Since the unique name of a part begins in column 19, it is recommended that the user incorporate the unique name, along with the part type for the name of the file generated. Although mentioned in Section 2.1, for user convenience, a list of commands and a brief description of the data follows:

*ENGINE - indicates that engine data is to follow.

*FULL CONVERTER - indicates that torque converter data is to follow specifying input and output torques and RPM's.

*S.R. CONVERTER - indicates that torque converter data is to follow specifying input torque and RPM along with a speed ratio and a torque ratio.

*VEHICLE - indicates that gross vehicle data (weight, frontal area, rear axle ratio, etc.) is to follow.

*GEAR - indicates that data for a single gear is to follow.

*SHIFT LOGIC - indicates that the shift criteria (shift lines, shift time, etc) are to follow for all the gears in the transmission.

*ACCESSORY - indicates that data for an engine accessory (fan, air conditioner, etc) is to follow.

*DRIVING SCHEDULE - indicates that data, in segment form, describing the particular driving schedule (segment number, acceleration, speed, time, etc) is to follow.

*ROUTE - indicates that data describing the physical route (distance, grade, etc) to be driven is to follow; the grade and road coefficient specifications are from the last, up to the current data point milepost.

*TIRE - indicates that data for a tire type is to follow.

*REAR AXLE - indicates that rear axle data is to follow.

*TRANSMISSION - indicates that a transmission part name will follow (specifies a list of gears).

Now that a particular part file has been created, the user may load that part and store it permanently on the disk as a core image in a parts base for VEHSIM. The general form is:

@FILE.EXT

As long as the user runs the model and loads the file, as above, VEHSIM will automatically put the file, in core image, into its correct parts file (i.e. VSMSLG.BIN, VSMENG.BIN, VSMROV.BIN.

The user may also use a card deck to create new parts and add them to the existing parts.

3. SAMPLE SIMULATIONS

This chapter provides sample simulations based on the procedures described in Chapter II. Each mode of operation is preceded by a title. All other OUTPUT is taken from actual runs off a liner printer or remote terminal. Words or phrases underlined (as in the ask mode) are user inputs.

3.1 LOADING THE PROGRAM

```
.LOAD %"OTS:NONSHAR" VSMWRK.FOR,VEHMAC.MAC
FORTRAN: VSMWRK
00025◆          PARAMETER NMOD=25,NPART=11,NCOM=41
%FTNSOD LINE:00025  PARAMETER STATEMENT OUT OF ORDER

%FTNWRN   ASCIZ         NO FATAL ERRORS AND 1 WARNINGS
CONVTR
DEBUG
DSK
DSKCTR
DSKDEL
DSKDIR
DSKRD
DSKWR
ENGINE
ENTERP
GETACL
00029◆          PARAMETER NMOD=25,NPART=11,NCOM=41
%FTNSOD LINE:00029  PARAMETER STATEMENT OUT OF ORDER

%FTNWRN   GOBACK        NO FATAL ERRORS AND 1 WARNINGS
00022◆          PARAMETER NMOD=25,NPART=11,NCOM=41
%FTNSOD LINE:00022  PARAMETER STATEMENT OUT OF ORDER

%FTNWRN   HLPCMD        NO FATAL ERRORS AND 1 WARNINGS
SKPREC
%FTNMVC LINE:00264 NUMBER OF VARIABLES DOES NOT EQUAL THE NUMBER OF CONS
TANTS IN DATA STATEMENT

%FTNWRN   INPBAT        NO FATAL ERRORS AND 1 WARNINGS
INPDIA
ITERAT
KPTIME
LOCKUP
MODEL
NOPART
PRNOUT
PRNTPD
RCRCNT
NWRCNT
ICRCNT
READPD
REMAP
SCALEN
SHIFTS
SIMCTR
SIMINT
00026◆          PARAMETER NMOD=25,NPART=11,NCOM=41
%FTNSOD LINE:00026  PARAMETER STATEMENT OUT OF ORDER
```

```
%FTNWRN   SIMLPT         NO FATAL ERRORS AND 1 WARNINGS
SIMSTS
SLOOKP
VALIDS
VSMBLK
VSMCTR
ZERO
ZVRDSV
LINK:   LOADING

EXIT

.SSAV VEHSIM
VEHSIM SAVED

.DEL VSMWRK.REL
FILES DELETED:
VSMWRK.REL
275 BLOCKS FREED

.RUN VEHSIM
```

3.2 INDIRECT SIMULATION

```
VEHSIM CAR    06(23) 16-MAR-81    17:13 JOB# 31 TTY051   DSKB   :[04132,402]

◆@VOLKS.VSM

◆OUTPUT      VOLKS.DAT[3,3]

LPT FILE 031VSM.DAT/DISP: DEL

LPT FILE DSKB   :031VSM.DAT[04132,402]<100>/DISPOSE:DEL

◆LIMIT PRINT        OFF
◆TITLE       VOLKSWAGON DIESEL STUDY
◆USE  VWRB90        VEHICLE
◆USE  F8VAG0.048    ENGINE            1       1 2 3 4
◆LOCKUP CONVERTER GEAR             1 2 3 4
◆USE  EPA4          SHIFT LOGIC
◆USE  VWRB905SP     TRANSMISSION
◆USE  CODY1         CONVERTER
◆USE  COCY1         CONVERTER
◆USE  LALY1         ACCESSORY
◆USE  ZGRADE        ROUTE
◆MODIFY             WEIGHT        2275.
◆MODIFY             DYNAM        -6.800
◆MODIFY             REAR AXLE R   3.900
◆MODIFY             DISPLACE      90.00
◆MODIFY             C1            .0090
◆MODIFY             C2           .00005
◆LIMIT PRINT        OFF
◆TITLE       BASE LINE CASE WITH URBAN AND HIGHWY
!URBAN AND HIGHWAY ONLY
◆LIMIT PRINT        OFF
◆USE  URBAN         DRIVING SCHEDULE
[DSK-DRS/NSEC:  2/NSEG:  50]
[DSK-DRS/NSEC:  3/NSEG:  15/LAST SECTION]
◆LIMIT PRINT        SEGMENT
◆SIMULATE           CAR          DIALOGUE

◆SIM
```

```
[SIMULATING]
[REACHED INITIAL CONDITIONS]
ESEG:  1 CUMT:   20.00 CUMD:   0.000 MPH:  0.0 CPUS:  0.08 CPUT:    0.08

ESEG:  2 CUMT:   27.44 CUMD:   0.022 MPH: 21.0 CPUS:  0.70 CPUT:    0.80

ESEG:  3 CUMT:   36.44 CUMD:   0.075 MPH: 21.0 CPUS:  0.02 CPUT:    0.82

ESEG:  4 CUMT:   39.47 CUMD:   0.090 MPH: 15.0 CPUS:  0.28 CPUT:    1.12

ESEG:  5 CUMT:   44.47 CUMD:   0.111 MPH: 15.0 CPUS:  0.01 CPUT:    1.15
↑N↑N
ESEG:  8 CUMT:   56.56 CUMD:   0.181 MPH: 16.0 CPUS:  0.31 CPUT:    1.90

ESEG:  9 CUMT:   57.56 CUMD:   0.185 MPH: 16.0 CPUS:  0.09 CPUT:    2.01

ESEG: 10 CUMT:   61.96 CUMD:   0.210 MPH: 25.0 CPUS:  0.46 CPUT:    2.48

ESEG: 11 CUMT:   79.96 CUMD:   0.335 MPH: 25.0 CPUS:  0.10 CPUT:    2.60
↑N
[DSK-DRS/NSEC:  2/NSEG:  50]↑N
ESEG: 67 CUMT:  798.76 CUMD:   4.780 MPH: 28.0 CPUS:  3.99 CPUT:   57.42

ESEG: 68 CUMT:  820.76 CUMD:   4.951 MPH: 28.0 CPUS:  0.02 CPUT:   57.46

ESEG: 69 CUMT:  825.65 CUMD:   4.993 MPH: 33.0 CPUS:  0.57 CPUT:   58.04

ESEG: 70 CUMT:  835.65 CUMD:   5.084 MPH: 33.0 CPUS:  0.02 CPUT:   58.08
↑N↑N
ESEG: 96 CUMT: 1215.83 CUMD:   7.056 MPH: 23.0 CPUS:  2.21 CPUT:   77.71

ESEG: 97 CUMT: 1220.83 CUMD:   7.092 MPH: 23.0 CPUS:  0.04 CPUT:   77.74

ESEG: 98 CUMT: 1227.98 CUMD:   7.110 MPH:  0.0 CPUS:  0.54 CPUT:   78.30

ESEG: 99 CUMT: 1237.98 CUMD:   7.110 MPH:  0.0 CPUS:  0.01 CPUT:   78.31

ESEG:100 CUMT: 1241.80 CUMD:   7.117 MPH: 13.0 CPUS:  0.41 CPUT:   78.73

[DSK-DRS/NSEC:  3/NSEG:  15/LAST SECTION]
ESEG:101 CUMT: 1247.80 CUMD:   7.139 MPH: 13.0 CPUS:  0.01 CPUT:   78.39

ESEG:102 CUMT: 1254.25 CUMD:   7.169 MPH: 21.0 CPUS:  0.58 CPUT:   79.↑N
49

ESCD:URBAN        CUMT: 1409.76  CUMD:   7.724  MPG: 39.3  CPUT: 84.06
```

```
          VEHICLE PERFORMANCE SIMULATION   16-MAR-81
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          ****************************************


RUN TITLE = BASE LINE CASE WITH URBAN AND HIGHWY

SCHEDULE AVERAGES      FUEL ECONOMY      = 39.34 MPG
                       WORK PER MILE     =  0.24 HP-HR/MI
                       AVG SP FUEL CONS  =  0.76 LBS/HP-HR
                       AVG SPEED         = 19.7  MPH


ADDITIONAL RUN DATA

  DRIVING SCHEDULE NAME = URBAN         ROUTE NAME            = %DYNO
    (  6.8)
  VEHICLE NAME          = VWRB80        ENGINE NAME           = FSVAGU.04
3
  CONVERTER NAME        = COLV1         SHIFT LOGIC NAME      = EPA4

  WEIGHT (LBS)          =  2375.        STROKE (INCHES)       =   2.87
  DISPLACEMENT (CU IN)  =   90.0        REAR AXLE RATIO       =   3.90
  WIND VELOCITY (MPH)   =    0.0        FUEL DENSITY (LB/GAL) =   7.09
  AERO DRAG  = 20.10 , 0.40             TIRES  =    9.00 , 0.05 , 1.00
                                         N/V   =  45.10


TOTALS                    TOTAL         PERCENT OF TOTAL
        VARIABLE (UNITS) AMOUNT (CRUISE ACCEL  DECEL   IDLE ) (BRAKES)
        -------- ------- ------  ------ ------ ------ ------   ------
        TIME     (SECS) 1409.6    35.7   24.4   21.8   18.1
        DISTANCE (MILES)   7.7    47.8   28.1   24.1    0.0
        ENERGY   (HP-HR)   1.82   28.0   65.6    4.5    1.9
        FUEL     (LBS)     1.39   32.7   45.0   16.1    6.2      9.5
```

```
ENERGY SUPPLY                            HP-HR
                                         -----
                  (1) ENGINE           =    1.82
                  (2) KINETIC ENERGY   =    0.00
                  (3) POTENTIAL ENERGY =    0.00
                  (4) ROTATING INERTIA =    0.00


BREAKDOWN                       PERCENT ENGINE HP-HR
                                --------------------
                  (1) ACCESSORIES      =   4.69
                  (2) TORQUE CONVERTER =   0.06
                  (3) CLUTCH           =   0.02
                  (4) GEAR BOX         =   2.05
                  (5) DIFFERENTIAL     =   2.98
                  (6) TIRE SLIP        =   0.00
                              3+4+5+6  =   5.05
                            2+3+4+5+6  =   5.11
                  (7) AERODYNAMIC DRAG =  28.91
                  (8) ROLLING RESIST   =  28.20
                        SUBTOTAL 1- 8  =  66.92
                  (9) BRAKES           =  24.07
                 (10) ENGINE MOTORING  =   9.69
                        SUBTOTAL 1-10  = 100.68
                 (11) OTHER ENERGY     =   0.00
                           TOTAL 1-11  = 100.68

*EXIT

LPT FILE VOLKS.DAT /DISP: PRINT

LPT FILE DSK    :VOLKS.DAT [00003,003]<100>/DISPOSE:PRINT

STOP

END OF EXECUTION
CPU TIME: 1:30.93       ELAPSED TIME: 12:23.97
EXIT


.SUB/AFTER:18:00:00/TIME:00:20:00 VOLKS
[INP01:VOLKS=/SEQ:1185/TIME:0:20:00]
```

3.3 INTERACTIVE SIMULATION

```
RUN VEHSIM

VEHSIM CAR    06(23) 18-Mar-81    10:40 JOB#  8 TTY072  DSKB  :[04132,402]
*ASK

ENTER NUMBER OF ACCESSORIES TO BE USED: 1

ENTER PART NAME FOR ACCESSORY #  1: LALY1

ENTER PART NAME OF DRIVE CONVERTER TO BE USED: CODY1

ENTER PART NAME OF COAST CONVERTER TO BE USED: COCY1

ENTER PART NAME OF DRIVING SCHEDULE TO BE USED: URBAN

ENTER ENGINE NUMBER(1 OR 2), PART NAME, AND GEAR ASSIGNMENTS
: 1 F8VAG0.048 1 2 3 4

ENTER ENGINE NUMBER(1 OR 2), PART NAME, AND GEAR ASSIGNMENTS
:

ENTER PART NAME OF ROUTE TO BE USED: ZGRADE

ENTER PART NAME OF SHIFT LOGIC TO BE USED: EPA4

ENTER PART NAME OF VEHICLE TO BE USED: VWRB80

ENTER PART NAME OF TRANSMISSION (OR <CR> FOR GEARS): VWRB805SR
```

```
 VEHSIM CAR    06(23) STATUS REPORT
 -----------------------------------

DIALOGUE MODE /TTY
SIMULATION MODE-CAR
NO RUN TITLE
ENGINE(1)-F8VAG0.048
DRIVE CONVERTER-CODY1
COAST CONVERTER-COCY1
VEHICLE-VWRB80
TRANSMISSION - VWRB805SP
GEAR # 1-63.45        ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 2-61.94        ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 3-61.29        ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 4-60.97        ASSIGNED TO ENGINE-F8VAG0.048
ACCESSORY #  1-LALY1
DRIVING SCHEDULE-URBAN
SHIFT LOGIC-EPA4
ROUTE-ZGRADE
TIRE-%VEHICLE
NO GEARS LOCKED UP
GEARS UNLOCKED-  1  2  3  4
LIMIT PRINT-SUMMA  0.0000000E+00
DEBUG-OFF     0.0000000E+00  0.0000000E+00
TTY OUTPUT-OFF
LPT OUTPUT-ON
NO MODIFICATIONS

SIMULATE ? (ANS Y/N/D): N

ENTER GEAR NUMBERS TO BE LOCKED UP: 1 2 3 4

ENTER GEAR NUMBERS TO BE UNLOCKED:

*MODIFY(NEW VALUE,ITEM): 2375.0,WEIGH

*MODIFY(NEW VALUE,ITEM): -6.80,DYNAM

*MODIFY(NEW VALUE,ITEM): 3.90,REAR

*MODIFY(NEW VALUE,ITEM): 90.0,DISPL

*MODIFY(NEW VALUE,ITEM): 0.009,C1

*MODIFY(NEW VALUE,ITEM): 0.00005,C2

*MODIFY(NEW VALUE,ITEM):

*LIMIT PRINT: SEC

TTY OUTPUT(ON/OFF): OFF

DEBUG: OFF
```

```
 VEHSIM CAR     06(23) STATUS REPORT
 ------------------------------------

DIALOGUE MODE /TTY
SIMULATION MODE-CAR  /DYNAMOMETER
NO RUN TITLE
ENGINE(1)-F8VAG0.048
DRIVE CONVERTER-CODY1
COAST CONVERTER-COCY1
VEHICLE-VWRB80
TRANSMISSION - VWRB805SF
GEAR : 1-G3.45       ASSIGNED TO ENGINE-F8VAG0.048
GEAR : 2-G1.94       ASSIGNED TO ENGINE-F8VAG0.048
GEAR : 3-G1.29       ASSIGNED TO ENGINE-F8VAG0.048
GEAR : 4-G0.97       ASSIGNED TO ENGINE-F8VAG0.048
ACCESSORY :  1-LALY1
DRIVING SCHEDULE-URBAN
SHIFT LOGIC-EPA4
ROUTE-%DYNO
TIRE-%VEHICLE
GEARS LOCKED UP-  1  2  3  4
NO GEARS UNLOCKED
LIMIT PRINT-SECON   10.00000
DEBUG-OFF     0.0000000E+00  0.0000000E+00
TTY OUTPUT-OFF
LPT OUTPUT-ON
C1    MODIFIED FROM  .9000E-02 TO  .9000E-02
C2    MODIFIED FROM  .5000E-04 TO  .5000E-04
REAR  MODIFIED FROM  3.900     TO  3.900
WEIGH MODIFIED FROM  2375.     TO  2375.
DISPL MODIFIED FROM  88.95     TO  90.00
```

```
SIMULATE ? (ANS Y/N/D): Y

[SIMULATING]
[REACHED INITIAL CONDITIONS]
ESEG:  1 CUMT:   20.00 CUMD:   0.000 MPH:  0.0 CPUS:  0.01 CPUT:    0.07

ESEG:  2 CUMT:   27.44 CUMD:   0.022 MPH: 21.0 CPUS:  0.73 CPUT:    0.81

ESEG:  3 CUMT:   36.44 CUMD:   0.075 MPH: 21.0 CPUS:  0.02 CPUT:    0.83

ESEG:  4 CUMT:   39.47 CUMD:   0.090 MPH: 15.0 CPUS:  0.30 CPUT:    1.15

ESEG:  5 CUMT:   44.47 CUMD:   0.111 MPH: 15.0 CPUS:  0.03 CPUT:    1.19

ESEG:  6 CUMT:   48.14 CUMD:   0.130 MPH: 23.0 CPUS:  0.43 CPUT:    1.64

ESEG:  7 CUMT:   53.14 CUMD:   0.162 MPH: 23.0 CPUS:  0.01 CPUT:    1.67

ESEG:  8 CUMT:   56.56 CUMD:   0.181 MPH: 16.0 CPUS:  0.35 CPUT:    2.03

ESEG:  9 CUMT:   57.56 CUMD:   0.185 MPH: 16.0 CPUS:  0.0^N7 CPUT:    2.
11
^N
ESEG: 35 CUMT:  430.94 CUMD:   3.193 MPH: 30.0 CPUS:  2.99 CPUT:   34.68

ESEG: 36 CUMT:  434.94 CUMD:   3.226 MPH: 30.0 CPUS:  0.01 CPUT:   34.70

ESEG: 37 CUMT:  445.49 CUMD:   3.270 MPH:  0.0 CPUS:  0.97 CPUT:   35.69

ESEG: 38 CUMT:  463.49 CUMD:   3.270 MPH:  0.0 CPUS:  0.03 CPUT:   35.73
^N
[DSK-DPS/NSEC:  2/NSEG:  50]^N
ESEG: 96 CUMT: 1215.83 CUMD:   7.056 MPH: 23.0 CPUS:  2.48 CPUT:   83.28

ESEG: 97 CUMT: 1220.83 CUMD:   7.088 MPH: 23.0 CPUS:  0.03 CPUT:   83.33
^N


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          ****************************************


RUN TITLE =

SCHEDULE AVERAGES      FUEL ECONOMY       = 39.34 MPG
                       WORK PER MILE      =  0.24 HP-HR/MI
                       AVG SP FUEL CONS   =  0.76 LBS/HP-HR
                       AVG SPEED          = 19.7  MPH


ADDITIONAL RUN DATA

  DRIVING SCHEDULE NAME = URBAN        ROUTE NAME               = %DYNO
    (   5.8)
  VEHICLE NAME          = VWRB80       ENGINE NAME              = FSVAG0.04
8
  CONVERTER NAME        = CDCY1        SHIFT LOGIC NAME         = EPA4

  WEIGHT (LBS)          =  2375.       STROKE (INCHES)          =   2.89
  DISPLACEMENT (CU IN)  =   90.0       REAR AXLE RATIO          =   3.90
  WIND VELOCITY (MPH)   =    0.0       FUEL DENSITY (LB/GAL)    =   7.09
  AERO DRAG  = 20.10 , 0.40            TIRES  =    9.00 , 0.05 , 1.00
                                        N/V   =  45.10
```

```
TOTALS                         TOTAL        PERCENT OF TOTAL
         VARIABLE (UNITS) AMOUNT (CRUISE ACCEL  DECEL   IDLE )  (BRAKES)
         -------- ------- ------  ------ ------ ------  ------  ------
         TIME     (SECS) 1409.8    35.7   24.4   21.8    18.1
         DISTANCE (MILES)    7.7   47.8   28.1   24.1     0.0
         ENERGY   (HP-HP)   1.82   28.0   65.6    4.5     1.9
         FUEL     (LBS)     1.39   32.7   45.0   16.1     6.2      9.5

ENERGY SUPPLY                                HP-HP
                                             -----
                  (1) ENGINE           =      1.82
                  (2) KINETIC ENERGY   =      0.00
                  (3) POTENTIAL ENERGY =      0.00
                  (4) ROTATING INERTIA =      0.00

BREAKDOWN                         PERCENT ENGINE HP-HP
                                  --------------------
                  (1) ACCESSORIES       =    4.69
                  (2) TORQUE CONVERTER  =    0.06
                  (3) CLUTCH            =    0.02
                  (4) GEAR BOX          =    2.05
                  (5) DIFFERENTIAL      =    2.98
                  (6) TIRE SLIP         =    0.00
                              3+4+5+6   =    5.05
                            2+3+4+5+6   =    5.11
                  (7) AERODYNAMIC DRAG  =   28.91
                  (8) ROLLING RESIST    =   28.20
                        SUBTOTAL 1- 8   =   66.92
                  (9) BRAKES            =   24.07
                 (10) ENGINE MOTORING   =    9.69
                        SUBTOTAL 1-10   =  100.68
                 (11) OTHER ENERGY      =    0.00
                           TOTAL 1-11   =  100.68

*USE

PART TYPE: DRIV

ENTER PART NAME OF DRIVING SCHEDULE TO BE USED: EPAHWY

PART TYPE:

*MODIFY

*MODIFY(NEW VALUE,ITEM):
```

```
*SIM

[SIMULATING]
[REACHED INITIAL CONDITIONS]^N
ESEG:  3 CUMT:   26.36 CUMD:   0.161 MPH: 36.0 CPUS:  1.72 CPUT:    3.34

ESEG:  4 CUMT:   47.36 CUMD:   0.371 MPH: 36.0 CPUS:  0.02 CPUT:    3.39
^N^N
ESEG:  9 CUMT:  150.38 CUMD:   1.686 MPH: 44.0 CPUS:  2.84 CPUT:    8.91

ESEG: 10 CUMT:  166.37 CUMD:   1.890 MPH: 48.0 CPUS:  1.69 CPUT:   10.62

ESEG: 11 CUMT:  171.37 CUMD:   1.957 MPH: 48.0 CPUS:  0.02 CPUT:   ^N10.
66
^N
ESEG: 17 CUMT:  296.58 CUMD:   3.497 MPH: 29.0 CPUS:  1.23 CPUT:   15.52

ESEG: 18 CUMT:  299.58 CUMD:   3.521 MPH: 29.0 CPUS:  0.01 CPUT:   15.55
^N^N
ESEG: 27 CUMT:  482.78 CUMD:   6.337 MPH: 55.0 CPUS:  1.32 CPUT:   25.27

ESEG: 28 CUMT:  556.78 CUMD:   7.467 MPH: 55.0 CPUS:  0.02 CPUT:   25.32
^N
^N
ESEG: 38 CUMT:  718.79 CUMD:   9.769 MPH: 59.0 CPUS:  2.42 CPUT:   38.11

ESEG: 39 CUMT:  722.79 CUMD:   9.835 MPH: 59.0 CPUS:  0.01 CPUT:   38.14

ESEG: 40 CUMT:  745.79 CUMD:  10.180 MPH: 49.0 CPUS:  2.26 CPUT:   40.40
^N
ESCD:EPAHWY       CUMT:  768.95  CUMD:  10.299  MPG: 49.0  CPUT: 42.58

          VEHICLE PERFORMANCE SIMULATION   18-Mar-81
                     PAGE   5
          ****************************************


RUN TITLE =

SCHEDULE AVERAGES         FUEL ECONOMY        = 48.97 MPG
                          WORK PER MILE       =   0.24 HP-HR/MI
                          AVG SP FUEL CONS    =   0.59 LBS/HP-HR
                          AVG SPEED           = 48.2  MPH


ADDITIONAL RUN DATA

  DRIVING SCHEDULE NAME = EPAHWY        ROUTE NAME              = %DYNO
    (  6.8)
  VEHICLE NAME             = VWPB80      ENGINE NAME             = FSVAG0.04
8
  CONVERTER NAME           = COCY1       SHIFT LOGIC NAME        = EPA4

  WEIGHT (LBS)             =   2375.     STROKE (INCHES)         =    2.89
  DISPLACEMENT (CU IN)     =    90.0     REAR AXLE RATIO         =    3.90
  WIND VELOCITY (MPH)      =     0.0     FUEL DENSITY (LB/GAL)   =    7.09
  AERO DRAG  = 20.10 , 0.40              TIRES  =    9.00 , 0.05 , 1.00
                                          N/V   =  45.10

TOTALS                        TOTAL          PERCENT OF TOTAL
          VARIABLE  (UNITS)  AMOUNT (CRUISE ACCEL  DECEL    IDLE )  (BRAKES)
          --------  -------  ------  ------ ------ ------  ------    ------
          TIME      (SECS)   769.0    55.1   22.5   21.8    0.7
          DISTANCE  (MILES)   10.3    58.1   20.9   21.0    0.0
          ENERGY    (HP-HR)    2.52   55.6   33.6   10.8    0.0
          FUEL      (LBS)      1.49   56.1   28.7   15.1    0.1       1.7
```

```
ENERGY SUPPLY                             HP-HR
                                          -----
                   (1) ENGINE           =     2.52
                   (2) KINETIC ENERGY   =     0.00
                   (3) POTENTIAL ENERGY =     0.00
                   (4) ROTATING INERTIA =     0.00

BREAKDOWN                       PERCENT ENGINE HP-HR
                                --------------------
                  (1) ACCESSORIES      =   2.29
                  (2) TORQUE CONVERTER =   0.01
                  (3) CLUTCH           =   0.00
                  (4) GEAR BOX         =   2.00
                  (5) DIFFERENTIAL     =   2.93
                  (6) TIRE SLIP        =   0.00
                                3+4+5+6 =   4.93
                              2+3+4+5+6 =   4.94
                  (7) AERODYNAMIC DRAG =  56.76
                  (8) ROLLING RESIST   =  29.84
                        SUBTOTAL 1- 8  =  93.83
                  (9) BRAKES           =   4.44
                 (10) ENGINE MOTORING  =   2.09
                        SUBTOTAL 1-10  = 100.36
                 (11) OTHER ENERGY     =   0.00
                           TOTAL 1-11  = 100.36

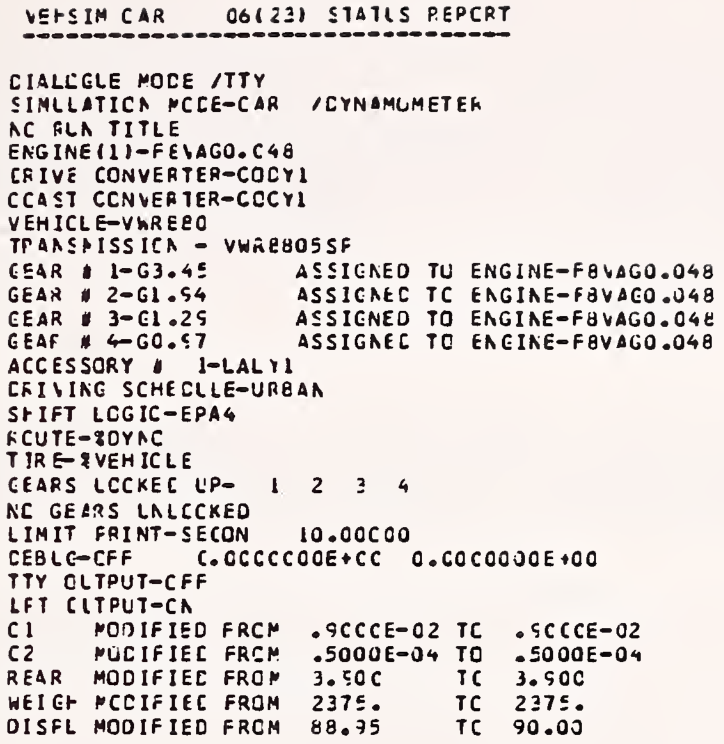
*EXIT

LPT FILE 008VSM.DAT/DISP: PRINT

LPT FILE DSKB  :008VSM.DAT[04132,402]<100>/DISPOSE:PRINT

STOP

END OF EXECUTION
CPU TIME: 2:20.86       ELAPSED TIME: 34:27.33
EXIT
```



```
 VEHSIM CAR     06(23) STATUS REPORT
 --------------------------------

DIALOGUE MODE /TTY
SIMULATION MODE-CAR  /DYNAMOMETER
NO RUN TITLE
ENGINE(1)-F8VAGO.048
DRIVE CONVERTER-COCY1
COAST CONVERTER-COCY1
VEHICLE-VWR880
TRANSMISSION - VWR8805SF
GEAR # 1-G3.45       ASSIGNED TO ENGINE-F8VAGO.048
GEAR # 2-G1.94       ASSIGNED TO ENGINE-F8VAGO.048
GEAR # 3-G1.29       ASSIGNED TO ENGINE-F8VAGO.048
GEAR # 4-G0.97       ASSIGNED TO ENGINE-F8VAGO.048
ACCESSORY #  1-LALY1
DRIVING SCHEDULE-URBAN
SHIFT LOGIC-EPA4
ROUTE-%DYNO
TIRE-%VEHICLE
GEARS LOCKED UP-  1  2  3  4
NO GEARS UNLOCKED
LIMIT PRINT-SECON    10.00000
DEBUG-OFF     0.0000000E+00  0.0000000E+00
TTY OUTPUT-OFF
PLT OUTPUT-ON
C1     MODIFIED FROM  .9000E-02 TO  .9000E-02
C2     MODIFIED FROM  .5000E-04 TO  .5000E-04
REAR   MODIFIED FROM  3.900     TO  3.900
WEIGH  MODIFIED FROM  2375.     TO  2375.
DISPL  MODIFIED FROM  88.95     TO  90.00
```

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18-MAR-81                          VEHICLE PERFORMANCE SIMULATION                                       PAGE   1
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                          RUN TITLE (                                                            )
                          ------------------------------------------------------------------------

                             DRIVING SCHEDULE ( URBAN       )        USING ROUTE ( NONE        )
                             ---------------------------------       ---------------------------

                               INST         CUM                                                                            CRS          GRADE-
   SEC.     MILES    MPH    ACC      MPG   BSFC  MPG GEAR    LOAD      HPW      HPE    RPM   TORQ     VAC     SR    ETA PCT.ACT SEC  BRAKES  ABILITY
--------------------------------------------------------------------------------------------------------------------------------------------------

   0.00    0.000    0.0   0.00     0.00   2.53   0.0   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.    1     0.0     0.00
  20.00    0.000    0.0   0.00     0.00   2.53   0.0   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.    1     0.0     0.00
  36.44    0.075   21.0   0.00    46.45   1.38  19.6   2      2.1      2.1      2.5  2418.     5.     2.0  1.000  1.000    21.    3     0.0*********
  46.47    0.120   19.4   3.20    18.24   0.47  23.8   2      1.9     14.6     15.9  2229.    37.     1.7  1.000  1.000    71.    6     0.0    10.67
  56.49    0.180   16.1  -3.00    53.90  99.99  27.3   2      1.4     -2.6     -2.8  1859.    -8.     1.4  1.000  1.000     0.    8   126.7*********
  79.96    0.335   25.0   0.00    63.49   0.88  33.5   3      2.8      2.8      3.2  1914.     9.     1.5  1.000  1.000    28.   11     0.0*********
 119.13    0.655   30.0   0.00    59.31   0.83  41.1   3      3.9      3.9      4.3  2297.    10.     1.9  1.000  1.000    33.   13     0.0*********
 166.68    0.655    0.0   0.00     0.00   2.53  37.5   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.   15     0.0     0.00
 184.93    0.757   26.0   0.00    64.29   0.84  35.9   3      3.0      3.0      3.4  1991.     9.     1.5  1.000  1.000    29.   17     0.0*********
 195.19    0.856   23.9   2.60    20.06   0.50  35.9   2      2.6     15.4     16.8  2753.    32.     2.3  1.000  1.000    69.   20     0.0     6.65
 205.84    0.951   40.4   1.79    25.44   0.49  33.8   4      6.8     21.6     23.0  2328.    52.     1.8  1.000  1.000   100.   20     0.0     5.79
 222.37    1.175   47.0   0.00    55.11   0.61  34.9   4      9.2      9.2      9.9  2706.    19.     2.3  1.000  1.000    50.   21     0.0*********
 233.37    1.311   50.4   0.50    41.10   0.52  35.5   4     10.6     15.7     16.9  2902.    31.     2.4  1.000  1.000    67.   22     0.0     1.61
 243.37    1.455   53.8   0.50    39.37   0.51  35.9   4     12.2     17.6     18.9  3098.    32.     2.6  1.000  1.000    69.   22     0.0     1.61
 253.40    1.610   56.9  -0.30    55.52   0.66  36.2   4     13.6     10.2     11.0  3273.    18.     2.9  1.000  1.000    45.   23     0.0*********
 263.40    1.765   54.8  -0.30    57.43   0.67  37.4   4     12.6      9.3     10.0  3155.    17.     2.8  1.000  1.000    41.   23     0.0*********
 273.40    1.915   52.8  -0.30    59.63   0.69  38.5   4     11.7      8.4      9.1  3036.    16.     2.6  1.000  1.000    45.   23     0.0*********
 283.44    2.059   51.4   0.40    42.27   0.53  39.4   4     11.0     15.2     16.3  2958.    29.     2.5  1.000  1.000    64.   24     0.0     1.29
 293.44    2.205   54.1   0.40    41.02   0.52  39.5   4     12.3     16.7     17.9  3115.    30.     2.6  1.000  1.000    66.   24     0.0     1.29
 303.47    2.359   53.3  -1.30   119.38  99.99  40.1   4     11.9     -2.2     -2.1  3066.    -4.     2.7  1.000  1.000    18.   25     0.0*********
 313.47    2.494   44.4  -1.30   129.75  99.99  41.6   4      8.2     -3.5     -3.6  2555.    -7.     2.1  1.000  1.000     8.   25     0.0*********
 323.47    2.605   35.5  -1.30   118.58  99.99  42.9   4      5.3     -3.5     -3.5  2045.    -9.     1.6  1.000  1.000     0.   25     5.5*********
 333.75    2.693   24.8  -2.00    82.77  99.99  43.7   3      2.8     -2.9     -2.9  1896.    -8.     1.5  1.000  1.000     0.   26    61.9*********
 344.05    2.744   11.2  -2.00    37.26  99.99  43.9   2      0.8     -1.0     -1.0  1285.    -4.     0.9  1.000  1.000     0.   26    64.9*********
 360.82    2.751    0.0   0.00     0.00   2.53  43.4   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.   28     0.0     0.00
 371.20    2.794   23.9   1.50    26.20   0.59  42.4   2      2.6     10.0     11.0  2756.    21.     2.3  1.000  1.000    52.   30     0.0     4.58
 381.60    2.876   33.8   1.50    29.69   0.49  42.0   3      4.9     15.2     16.4  2590.    33.     2.1  1.000  1.000    70.   30     0.0     4.88
 400.71    3.067   36.0   0.00    53.39   0.80  42.4   3      5.5      5.5      6.0  2756.    11.     2.4  1.000  1.000    38.   31     0.0*********
 411.32    3.135    9.2  -5.00    20.71  99.99  42.8   1      0.7     -2.2     -2.9  1864.    -8.     1.5  1.000  1.000     0.   33   254.6*********
 421.32    3.140    7.1   4.50    12.16   0.50  42.4   1      0.5      7.1      8.2  1445.    30.     0.7  1.000  1.000    65.   35     0.0    16.26
 434.54    3.226   30.0   0.00    59.31   0.83  41.5   3      3.9      3.9      4.3  2297.    10.     1.9  1.000  1.000    33.   36     0.0*********
 445.54    3.270    0.0   0.00     0.00   2.53  41.5   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.   36     0.0     0.00
 463.49    3.270    0.0   0.00     0.00   2.53  41.1   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.   38     0.0     0.00
 474.25    3.317   28.0   2.20    24.59   0.47  40.2   3      3.4     16.0     17.2  2140.    42.     1.6  1.000  1.000    84.   40     0.0     7.17
 510.61    3.675   36.0   0.00    53.39   0.80  40.6   3      5.5      5.5      6.0  2756.    11.     2.4  1.000  1.000    38.   41     0.0*********
 520.89    3.747   12.7  -5.00    42.47  99.99  41.0   2      1.0     -1.2     -1.5  1469.    -5.     1.1  1.000  1.000     0.   43   252.9*********
 532.04    3.755    0.0   0.00     0.00   2.53  40.8   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.   44     0.0     0.00
 542.39    3.780   16.7   2.50    21.76   0.49  40.5   2      1.5     10.0     11.0  1920.    30.     1.3  1.000  1.000    64.   45     0.0     6.32
 563.27    3.919   25.0   0.00    63.49   0.88  40.6   3      2.8      2.8      3.2  1914.     9.     1.5  1.000  1.000    28.   46     0.0*********
 587.37    3.947    0.0   0.00     0.00   2.53  40.3   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.   48     0.0     0.00
 612.10    4.051   17.0   0.00    49.76   1.34  40.1   2      1.5      1.5      1.8  1957.     5.     1.5  1.000  1.000    22.   51     0.0*********
 622.10    4.106   22.5   0.80    33.65   0.71  40.0   2      2.4      6.0      6.7  2585.    14.     2.2  1.000  1.000    40.   52     0.0     2.65
 632.47    4.178   22.7  -5.00    15.90  99.99  40.0   3      2.4     -2.2     -2.3  1741.    -7.     1.3  1.000  1.000     0.   53   262.5*********
 665.92    4.202    0.0   0.00     0.00   2.53  39.6   1      0.0      0.0      0.5  1000.     3.     0.7  1.000  1.000    10.   54     0.0     0.00
 676.31    4.238   21.7   2.50    21.07   0.50  39.2   2      2.2     13.4     14.6  2502.    31.     2.0  1.000  1.000    67.   56     0.0     6.32
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18-MAR-81                          VEHICLE PERFORMANCE SIMULATION                                  PAGE   2
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                      RUN TITLE (                                                               )
                      -------------------------------------------------------------------------

                         DRIVING SCHEDULE ( URBAN        )      USING ROUTE ( XCYNC        )          17
                         --------------------------------      --------------------------

                                     INST         CUM                                                                          DRS          GRADE-
    SEC.     MILES    MPH    ACC      MPG   BSFC  MPG GEAR    HCLD      HPW      HPE   RPM   TORQ    VAC     SR    ETA PCT.ICT SEC BRAKES ABILITY
------------------------------------------------------------------------------------------------------------------------------------------------

  685.23     4.327   25.0   0.00    63.49   0.88 39.3   3      2.8      2.8      3.2 1914.     9.    1.5 1.000 1.000     26.    57    0.0********
  713.13     4.362    0.0   0.00     0.00   2.53 39.1   1      0.0      0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    59    0.0     0.00
  723.13     4.381   13.6   2.00    17.75   0.69 38.9   1      1.1      6.6      7.9 2792.    15.    2.4 1.000 1.000     43.    60    0.0     7.15
  739.65     4.475   22.0   0.00    45.61   1.30 38.8   2      2.3      2.3      2.6 2533.     5.    2.1 1.000 1.000     26.    61    0.0********
  750.10     4.502    6.3   5.00    11.27   0.49 38.7   1      0.4      7.0      8.1 1251.    33.    0.7 1.000 1.000     72.    63    0.0    18.13
  776.53     4.700   28.0   0.00    61.80   0.64 38.6   3      3.4      3.4      3.8 2144.     9.    1.7 1.000 1.000     31.    64    0.0********
  789.13     4.736    2.2   5.00     5.38   0.50 38.6   1      0.1      2.4      5.9 1000.    31.    0.7 1.000 1.000     71.    67    0.0    16.67
  820.76     4.951   28.0   0.00    61.80   0.84 38.6   3      3.4      3.4      3.8 2144.     9.    1.7 1.000 1.000     31.    68    0.0********
  835.65     5.064   33.0   0.00    56.25   0.81 38.7   3      4.6      4.6      5.1 2526.    11.    2.1 1.000 1.000     36.    70    0.0********
  852.05     5.223   30.0   0.00    59.31   0.83 39.1   3      3.9      3.9      4.3 2297.    10.    1.9 1.000 1.000     33.    72    0.0********
  862.31     5.251   19.0   1.30    29.73   0.60 39.4   2      1.8      6.9      7.6 2193.    16.    1.7 1.000 1.000     46.    75    0.0     4.31
  967.77     6.044   26.0   0.00    64.29   0.84 41.1   3      3.0      3.0      3.4 1991.     9.    1.5 1.000 1.000     29.    76    0.0********
  980.57     6.078    0.0   0.00     0.00   2.53 41.1   1      0.0      0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    78    0.0     0.00
 1003.25     6.216   28.0   0.00    61.60   0.64 40.8   3      3.4      3.4      3.8 2144.     9.    1.7 1.000 1.000     31.    80    0.0********
 1038.58     6.447   23.0   0.00    61.48   0.95 41.3   3      2.5      2.5      2.8 1761.     6.    1.4 1.000 1.000     27.    82    0.0********
 1076.08     6.471    0.0   0.00     0.00   2.53 40.9   1      0.0      0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    84    0.0     0.00
 1086.86     6.516   24.8   0.00    64.83   0.94 40.6   3      2.8      2.8      2.9 1899.     6.    1.4 1.000 1.000     27.    86    0.0********
 1096.18     6.601   27.0   0.00    63.13   0.84 40.7   3      3.2      3.2      3.6 2067.     9.    1.6 1.000 1.000     30.    87    0.0********
 1108.45     6.655   13.0  -1.00    43.36  99.99 40.8   2      1.0     -1.6     -1.5 1459.    -5.    1.1 1.000 1.000      0.    89    1.1********
 1118.80     6.662    6.1  -1.00    17.11  99.99 40.8   1      0.4     -0.9     -0.8 1254.    -4.    0.9 1.000 1.000      0.    89    0.0********
 1126.80     6.690    1.4   2.00     5.45   0.68 40.6   1      0.1      0.6      2.6 1000.    14.    0.7 1.000 1.000     34.    90    0.0     6.59
 1136.60     6.713   15.0   2.00    17.21   0.71 40.4   1      1.3      7.5      8.7 3071.    15.    2.7 1.000 1.000     44.    90    0.0     7.15
 1149.15     6.761   18.9   0.60    38.05   0.76 40.4   2      1.8      4.1      4.6 2176.    11.    1.7 1.000 1.000     34.    91    0.0     1.59
 1159.15     6.820   23.0   0.60    35.61   0.78 40.4   2      2.5      5.3      5.9 2649.    12.    2.2 1.000 1.000     36.    91    0.0     1.59
 1182.36     6.984   26.0   0.00    64.29   0.84 40.6   3      3.0      3.0      3.4 1991.     9.    1.5 1.000 1.000     29.    92    0.0********
 1192.96     7.031    1.4  -5.00     4.54  99.99 40.7   1      0.1     -0.2     -0.4 1000.    -2.    0.7 1.000 1.000      0.    94  302.0********
 1208.36     7.031    0.0   0.00     0.00   2.53 40.5   1      0.0      0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    95    0.0     0.00
 1220.83     7.088   23.0   0.00    44.92   1.28 40.2   2      2.5      2.5      2.8 2646.     6.    2.2 1.000 1.000     29.    97    0.0********
 1237.98     7.110    0.0   0.00     0.00   2.53 40.1   1      0.0      0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    99    0.0     0.00
 1248.00     7.140   13.3   2.00    17.91   0.69 39.9   1      1.1      6.6      7.7 2716.    15.    2.3 1.000 1.000     43.   102    0.0     7.15
 1274.25     7.286   21.0   0.00    46.45   1.31 39.9   2      2.1      2.1      2.5 2416.     5.    2.0 1.000 1.000     27.   103    0.0********
 1284.50     7.317    0.7  -3.00     2.21  99.99 39.9   1      0.0     -0.1     -0.4 1000.    -2.    0.7 1.000 1.000      0.   104  158.1********
 1294.50     7.317    3.4   3.00    11.34   0.57 39.7   1      0.2      2.3      3.7 1000.    20.    0.7 1.000 1.000     46.   106    0.0     9.52
 1304.74     7.343   10.0   0.00    30.66   2.34 39.7   1      0.7      0.7      1.0 2047.     3.    1.6 1.000 1.000     19.   107    0.0********
 1340.63     7.575   25.0   0.00    63.49   0.88 39.6   3      2.8      2.8      3.2 1914.     9.    1.5 1.000 1.000     26.   109    0.0********
 1373.73     7.604    0.0   0.00     0.00   2.53 39.6   1      0.0      0.0      0.5 1000.     3.    0.7 1.000 1.000     10.   111    0.0     0.00
 1394.66     7.696   20.0   0.00    47.43   1.31 39.4   2      2.0      2.0      2.3 2303.     5.    1.9 1.000 1.000     26.   113    0.0********
 1409.76     7.724    0.0   0.00     0.00   2.53 39.3   1      0.0      0.0      0.5 1000.     3.    0.7 1.000 1.000     10.   115    0.0     0.00
```

```
SHIFT FREQUENCY DATA BY GEAR                                18-MAR-81                  PAGE   3
----------------------------                                                           --------

  TOTAL SHIFTS  =    70      SHIFTS PER MILE  =   9.1     NUMB GEARS  =  4

  GEAR INTO     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20

  UPSHIFTS      0 18 16  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

  DOWNSHIFTS   18 16  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0




GEAR TIME DISTRIBUTION
----------------------

TRANSMISSION: VWR805SF             GEARS LOCKED UP:    1   2   3   4

 NO.         NAME:          RATIO:        %TIME:
----     ----------     ----------     ----------
   1     G3.45               3.450          32.05
   2     G1.94               1.940          21.73
   3     G1.29               1.290          37.36
   4     G0.97               0.970           8.86
   5     G0.76               0.760           0.00
```

```
VEHICLE PERFORMANCE SIMULATION   18-MAR-81                                                PAGE   4
*************************************************

RUN TITLE =

SCHEDULE AVERAGES        FUEL ECONOMY      = 39.34 MPG
                         WORK PER MILE     =  0.24 HP-HR/MI
                         AVG SP FUEL CONS  =  0.76 LBS/HP-HR
                         AVG SPEED         = 19.7  MPH


ADDITIONAL RUN DATA

  DRIVING SCHEDULE NAME = URBAN        ROUTE NAME                = *CYNO          (  6.8)
  VEHICLE NAME          = VWRBBO       ENGINE NAME               = F8VACO.048
  CONVERTER NAME        = CCCY1        SHIFT LOGIC NAME          = EPA4
  WEIGHT (LBS)          =  2375.       STROKE (INCHES)           =   2.89
  DISPLACEMENT (CU IN)  =    90.0      REAR AXLE RATIO           =   3.90
  WIND VELOCITY (MPH)   =     0.0      FUEL DENSITY (LB/GAL) =   7.09
  AERO DRAG  = 20.10 , 0.40            TIRES  =    9.00 , 0.05 , 1.00
                                        N/V   =  45.10

TOTALS                         TOTAL         PERCENT OF TOTAL
          VARIABLE (UNITS) AMOUNT (CRUISE ACCEL  DECEL   IDLE ) (BRAKES)
          -------- ------- ------  ------ ------ ------ ------   ------
          TIME     (SECS) 1409.8   35.7   24.4   21.8   18.1
          DISTANCE (MILES)   7.7   47.8   28.1   24.1    0.0
          ENERGY   (HP-HR)  1.82   28.0   65.6    4.5    1.9
          FUEL     (LBS)    1.39   32.7   45.0   16.1    6.2       9.5

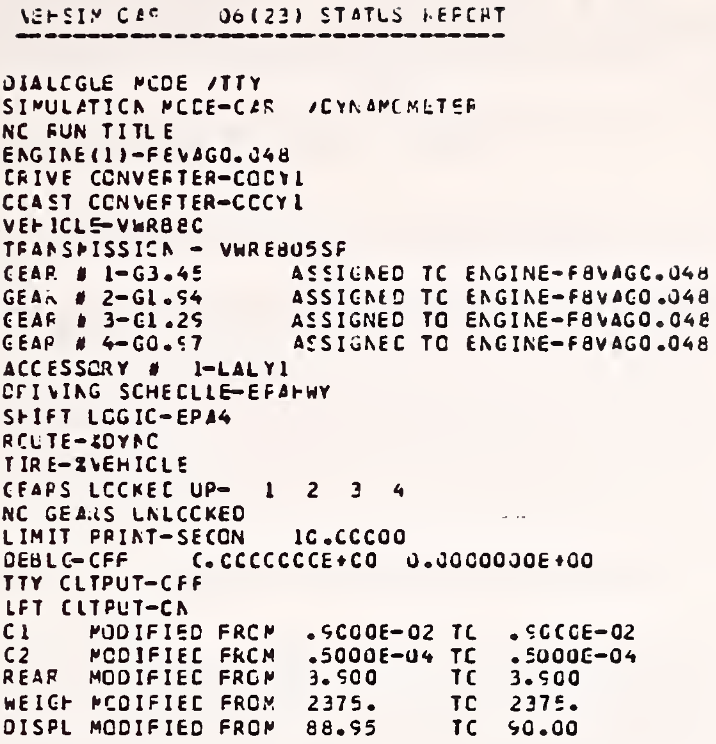
ENERGY SUPPLY                                HP-HR
                                             -----
                    (1) ENGINE           =    1.82
                    (2) KINETIC ENERGY   =    0.00
                    (3) POTENTIAL ENERGY =    0.00
                    (4) ROTATING INERTIA =    0.00

BREAKDOWN                         PERCENT ENGINE HP-HR
                                  --------------------
                    (1) ACCESSORIES      =    4.69
                    (2) TORQUE CONVERTER =    0.06
                    (3) CLUTCH           =    0.02
                    (4) GEAR BOX         =    2.05
                    (5) DIFFERENTIAL     =    2.98
                    (6) TIRE SLIP        =    0.00
                              3+4+5+6    =    5.05
                            2+3+4+5+6    =    5.11
                    (7) AERODYNAMIC DRAG =   28.91
                    (8) ROLLING RESIST   =   28.20
                          SUBTOTAL 1- 8  =   66.92
                    (9) BRAKES           =   24.07
                   (10) ENGINE MOTORING  =    9.69
                          SUBTOTAL 1-10  =  100.68
                   (11) OTHER ENERGY     =    0.00
                             TOTAL 1-11  =  100.68
```

```
VEHICLE PERFORMANCE SIMULATION   18-MAR-81                                          PAGE   5
*********************************************

BREAKDOWN OF % TIME SPENT ON VARIOUS PARTS OF ENGINE MAP

     -20.0    -10.0      0.0     10.0     20.0     30.0     40.0     50.0     60.0     70.0     80.0     90.0    100.0    110.0    120.0
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
  900.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |    0.0 |   -0.4 |    0.5 |    3.0 |    5.1 |    6.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |    0.0 |   -2.2 |    2.5 |   15.6 |   26.2 |   31.1 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |     0. |  1030. |  1000. |  1013. |  1018. |  1020. |     0. |     0. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    0.0 |    3.3 |   18.1 |    1.0 |    0.6 |    1.2 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 1200.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |    0.0 |   -1.1 |    0.2 |    4.0 |    6.5 |    8.4 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |    0.0 |   -4.4 |    0.8 |   15.6 |   25.4 |   32.9 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |     0. |  1353. |  1351. |  1346. |  1352. |  1343. |     0. |     0. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    0.0 |    2.1 |    0.1 |    0.2 |    0.2 |    0.3 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 1500.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |    0.0 |   -2.0 |    2.3 |    4.4 |    8.6 |   10.5 |   13.6 |   17.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |    0.0 |   -6.4 |    6.8 |   13.8 |   26.6 |   33.4 |   40.0 |   50.8 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |     0. |  1660. |  1745. |  1689. |  1704. |  1657. |  1779. |  1757. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    0.0 |    4.1 |    2.7 |    0.3 |    0.2 |    0.4 |    0.0 |    0.2 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 1800.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |    0.0 |   -3.0 |    3.1 |    5.1 |    8.8 |   12.2 |   16.8 |   19.2 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |    0.0 |   -6.1 |    8.2 |   13.6 |   23.5 |   32.6 |   44.3 |   51.5 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |     0. |  1941. |  1968. |  1963. |  1966. |  1972. |  1990. |  1964. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    0.0 |    4.6 |   16.6 |    1.0 |    1.2 |    1.1 |    0.4 |    1.1 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 2100.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |   -4.6 |   -3.7 |    3.8 |    5.9 |   10.0 |   14.0 |   19.0 |   22.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |  -10.6 |   -8.9 |    9.0 |   13.7 |   23.5 |   32.5 |   44.5 |   51.6 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |  2263. |  2197. |  2223. |  2256. |  2236. |  2253. |  2245. |  2243. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    1.4 |    1.3 |    8.1 |    1.2 |    0.8 |    1.5 |    0.4 |    0.8 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 2400.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |   -6.0 |   -3.1 |    2.4 |    6.3 |   11.0 |   15.9 |   22.4 |   25.3 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |  -12.4 |   -6.5 |    5.1 |   13.0 |   22.9 |   32.9 |   46.2 |   52.1 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |  2539. |  2525. |  2507. |  2542. |  2528. |  2542. |  2550. |  2546. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    0.6 |    0.6 |    3.9 |    2.0 |    0.4 |    1.4 |    0.3 |    0.7 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 2700.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |   -7.5 |   -2.8 |    3.2 |    7.1 |   15.0 |   17.2 |   23.7 |   27.9 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |  -14.1 |   -5.2 |    5.9 |   13.5 |   27.7 |   31.7 |   45.7 |   51.9 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |  2790. |  2850. |  2878. |  2773. |  2840. |  2857. |  2725. |  2822. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    0.2 |    0.4 |    0.0 |    5.7 |    0.9 |    1.4 |    0.1 |    0.4 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 3000.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
       |    0.0 |   -1.9 |    3.8 |    9.9 |   16.9 |   19.0 |    0.0 |   29.5 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |    0.0 |   -3.3 |    6.4 |   16.6 |   29.2 |   31.7 |    0.0 |   51.1 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
       |     0. |  3112. |  3075. |  3134. |  3046. |  3140. |     0. |  3035. |     0. |     0. |     0. |     0. |     0. |     0. |
       |    0.0 |    0.3 |    0.0 |    1.8 |    0.5 |    1.7 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |    0.0 |
 3300.-------------------------------------------------------------------------------------------------------------------------------
```



```
VEHSIM CAR    06(23) STATUS REPORT
----------------------------------

DIALOGUE MODE /TTY
SIMULATION MODE-CAR  /DYNAMOMETER
NO RUN TITLE
ENGINE(1)-F8VAG0.048
DRIVE CONVERTER-CDCY1
COAST CONVERTER-CCCY1
VEHICLE-VWR80C
TRANSMISSION - VWRE805SF
GEAR # 1-G3.45       ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 2-G1.94       ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 3-G1.29       ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 4-G0.97       ASSIGNED TO ENGINE-F8VAG0.048
ACCESSORY #  1-LALY1
DRIVING SCHEDULE-EPAHWY
SHIFT LOGIC-EPA4
ROUTE-%DYNC
TIRE-%VEHICLE
GEARS LOCKED UP-  1  2  3  4
NO GEARS UNLOCKED
LIMIT PRINT-SECON   10.00000
DEBUG-OFF     0.00000000E+00  0.00000000E+00
TTY OUTPUT-OFF
LPT OUTPUT-ON
C1    MODIFIED FROM  .9000E-02 TO  .9000E-02
C2    MODIFIED FROM  .5000E-04 TO  .5000E-04
REAR  MODIFIED FROM  3.900     TO  3.900
WEIGH MODIFIED FROM  2375.     TO  2375.
DISPL MODIFIED FROM  88.95     TO  90.00
```

```
18-MAR-81                          VEHICLE PERFORMANCE SIMULATION                          PAGE   1
---------                          ------------------------------                          --------

                     RUN TITLE (                                                          )
                     ----------------------------------------------------------------------

                        DRIVING SCHEDULE ( EPAHWY     )        USING ROUTE ( BEVAC       )
                        ----------------------------------     ---------------------------

                                INST         CUM                                                                           CRS          GRACE-
  SEC.    MILES    MPH    ACC    MPG  BSFC   MPG  GEAR   RCLC    HPW     HPE   RPM  TORQ    VAC     SR    ETA  PCT.ACT  SEC  BRAKES  ABILITY
--------------------------------------------------------------------------------------------------------------------------------------------

  0.00    0.000    0.0   0.00   0.00  2.53   0.0   1      0.0    0.0     0.5  1000.   3.    0.7  1.000  1.000   10.      1   0.0      0.00
 10.35    0.027   22.6   4.24  13.50  0.48  12.9   2      2.4   22.0    23.9  2598.  48.    2.0  1.000  1.000   94.      2   0.0     14.19
 20.76    0.108   32.0   1.05  35.30  0.53  23.3   3      4.4   11.2    12.1  2450.  26.    1.9  1.000  1.000   99.      3   0.0      3.41
 47.36    0.371   36.0   0.00  53.39  0.80  36.7   3      5.5    5.5     6.0  2756.  11.    2.4  1.000  1.000   38.      4   0.0*********
 57.71    0.483   42.0   0.93  37.81  0.48  36.7   4      7.3   15.3    16.3  2417.  36.    1.9  1.000  1.000   74.      5   0.0      2.99
137.23    1.536   46.0   0.00  54.11  0.61  45.6   4      9.6    9.6    10.4  2763.  20.    2.3  1.000  1.000   50.      6   0.0*********
147.23    1.649   40.2   1.79  25.43  0.49  46.7   4      6.8   21.4    22.9  2316.  52.    1.8  1.000  1.000  100.      9   0.0      5.80
157.28    1.712   45.7   0.37  46.26  0.54  45.9   4      8.7   12.1    13.0  2632.  26.    2.1  1.000  1.000   60.     10   0.0      1.18
171.37    1.957   48.0   0.00  54.11  0.61  46.8   4      9.6    9.6    10.4  2763.  20.    2.3  1.000  1.000   50.     11   0.0*********
222.38    2.570   43.0   0.00  59.30  0.62  49.3   4      7.7    7.7     8.3  2475.  18.    2.1  1.000  1.000   46.     13   0.0*********
232.38    2.695   46.8   0.56  41.86  0.51  49.0   4      9.1   14.5    15.6  2697.  30.    2.2  1.000  1.000   66.     14   0.0      1.82
269.38    3.188   46.0   0.00  54.11  0.61  49.5   4      9.6    9.6    10.4  2763.  20.    2.3  1.000  1.000   50.     15   0.0*********
279.38    3.316   44.4  -0.52  62.30  0.59  50.3   4      8.2    3.5     3.9  2558.   8.    2.2  1.000  1.000   32.     16   0.0*********
289.38    3.431   36.5  -1.58 121.96 99.99  51.2   4      5.6   -3.7    -3.8  2103.  -9.    1.7  1.000  1.000    0.     17  22.6*********
299.63    3.521   29.1   2.72  19.99  0.48  51.7   3      3.7   19.8    21.3  2221.  50.    1.7  1.000  1.000   97.     19   0.0      6.69
309.92    3.629   42.6   0.43  46.85  0.53  50.1   4      7.6   11.3    12.2  2454.  26.    2.0  1.000  1.000   59.     20   0.0      1.39
319.92    3.751   45.6   0.43  44.97  0.53  49.9   4      8.7   12.6    13.6  2624.  27.    2.1  1.000  1.000   61.     20   0.0      1.39
329.92    3.883   50.5   1.01  32.80  0.49  49.4   4     10.7   21.0    22.5  2909.  41.    2.4  1.000  1.000   81.     21   0.0      3.26
339.92    4.033   57.4   1.01  30.59  0.49  48.4   4     13.9   25.7    27.4  3305.  44.    2.8  1.000  1.000   89.     21   0.0      3.26
415.77    5.255   58.0   0.00  46.86  0.57  48.0   4     14.2   14.2    15.3  3339.  24.    2.9  1.000  1.000   58.     22   0.0*********
425.77    5.419   60.0   0.00  45.81  0.57  47.7   4     15.3   15.3    16.4  3454.  25.    3.0  1.000  1.000   59.     24   0.0*********
435.77    5.584   58.3  -0.24  52.65  0.63  47.8   4     14.4   11.5    12.4  3358.  19.    3.0  1.000  1.000   51.     25   0.0*********
472.78    6.180   58.0   0.00  46.86  0.57  47.7   4     14.2   14.2    15.3  3339.  24.    2.9  1.000  1.000   58.     26   0.0*********
482.78    6.337   55.0  -0.44  62.46  0.74  48.0   4     12.7    7.8     8.5  3166.  14.    2.8  1.000  1.000   43.     27   0.0*********
556.78    7.467   55.0   0.00  48.50  0.59  48.1   4     12.7   12.7    13.7  3166.  23.    2.7  1.000  1.000   56.     28   0.0*********
566.78    7.618   53.5  -0.22  56.05  0.66  48.2   4     12.0    9.6    10.3  3078.  18.    2.7  1.000  1.000   48.     29   0.0*********
576.78    7.764   51.9  -0.22  57.58  0.66  48.3   4     11.3    8.9     9.7  2991.  17.    2.6  1.000  1.000   47.     29   0.0*********
586.78    7.907   50.4  -0.22  59.34  0.67  48.5   4     10.6    8.3     9.0  2903.  16.    2.5  1.000  1.000   46.     29   0.0*********
596.78    8.045   48.9  -0.22  61.22  0.67  48.6   4     10.0    7.7     8.4  2815.  16.    2.4  1.000  1.000   44.     29   0.0*********
606.78    8.178   47.4  -0.22  63.18  0.68  48.8   4      9.4    7.2     7.8  2727.  15.    2.3  1.000  1.000   43.     29   0.0*********
618.79    8.333   46.0   0.00  56.12  0.61  49.0   4      8.8    8.8     9.5  2646.  19.    2.2  1.000  1.000   49.     30   0.0*********
628.79    8.472   53.1   0.55  38.82  0.51  48.6   4     11.8   17.8    19.0  3058.  33.    2.6  1.000  1.000   70.     32   0.0      1.77
638.79    8.624   53.2  -2.64 177.58 99.99  48.6   4     11.9   -9.0    -9.3  3063. -16.    2.7  1.000  1.000    0.     34  50.4*********
648.79    8.756   47.1   0.81  27.30  0.49  48.8   4      9.3   17.1    18.3  2712.  35.    2.2  1.000  1.000   74.     36   0.0      2.63
695.79    9.418   51.0   0.00  51.23  0.60  48.7   4     10.9   10.9    11.7  2938.  21.    2.5  1.000  1.000   53.     37   0.0*********
705.79    9.564   54.5   0.51  38.50  0.51  48.6   4     12.5   18.1    19.4  3138.  32.    2.6  1.000  1.000   69.     38   0.0      1.65
715.79    9.721   58.0   0.51  37.42  0.51  48.4   4     14.2   20.2    21.6  3338.  34.    2.8  1.000  1.000   72.     38   0.0      1.65
725.79    9.883   57.7  -0.64  66.80  0.85  48.3   4     14.1    6.6     7.2  3321.  11.    2.9  1.000  1.000   40.     40   0.0*********
735.79   10.038   53.3  -0.64  73.73  0.93  48.6   4     11.9    5.0     5.5  3071.   9.    2.7  1.000  1.000   36.     40   0.0*********
745.79   10.180   49.0  -0.64  81.78  1.09  48.8   4     10.0    3.7     4.1  2821.   8.    2.4  1.000  1.000   33.     40   0.0*********
756.39   10.278   19.3  -4.40  64.39 99.99  49.1   2      1.8   -3.9    -4.3  2221. -10.    1.8  1.000  1.000    0.     41 208.4*********
768.95   10.299    0.0   0.00   0.00  2.53  49.0   1      0.0    0.0     0.5  1000.   3.    0.7  1.000  1.000   10.     43   0.0      0.00
```

```
SHIFT FREQUENCY DATA BY GEAR                           18-MAR-81                         PAGE  2
-----------------------------                                                            --------

  TOTAL SHIFTS  =      8      SHIFTS PER MILE  =   0.8     NUMB GEARS  =  4

  GEAR INTO     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
  UPSHIFTS      0  1  1  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  DOWNSHIFTS    1  1  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0




GEAR TIME DISTRIBUTION
----------------------

TRANSMISSION: VWR8805SF            GEARS LOCKED UP:    1   2   3   4

 NO.         NAME:         RATIO:        %TIME:
----     ----------    ----------    ----------
   1     G3.45              3.450          2.17
   2     G1.94              1.940          1.00
   3     G1.29              1.290          7.31
   4     G0.97              0.970         89.52
   5     G0.76              0.760          0.00
```

```
        VEHICLE PERFORMANCE SIMULATION   18-MAR-81                                          PAGE    3
        *********************************************

RUN TITLE =

SCHEDULE AVERAGES       FUEL ECONOMY       = 48.57 MPG
                        WORK PER MILE      =  0.24 HP-HR/MI
                        AVG SP FUEL CONS =   0.59 LBS/HP-HR
                        AVG SPEED          = 48.2  MPH

ADDITIONAL RUN DATA

  DRIVING SCHEDULE NAME = EPAHWY        ROUTE NAME              = 8DYAC        (  6.8)
  VEHICLE NAME          = VWRB80        ENGINE NAME             = F0VAC0.048
  CONVERTER NAME        = COCY1         SHIFT LOGIC NAME        = EPA4
  WEIGHT (LBS)          =  2375.        STROKE (INCHES)         =    2.89
  DISPLACEMENT (CU IN)  =    90.0       REAR AXLE RATIO         =    3.50
  WIND VELOCITY (MPH)   =     0.0       FUEL DENSITY (LB/GAL) =      7.09
  AERO DRAG   = 20.10 , 0.40            TIRES   =    5.00 , 0.05 , 1.00
                                         N/V    =  45.10

TOTALS                       TOTAL          PERCENT OF TOTAL
          VARIABLE (UNITS) AMOUNT (CRUISE ACCEL   DECEL    IDLE ) (BRAKES)
          -------- ------- ------  ------ ------  ------  ------   ------
          TIME     (SECS)  769.0    55.1   22.5    21.8     0.7
          DISTANCE (MILES)  10.3    58.1   20.9    21.0     0.0
          ENERGY   (HP-HR)   2.52   55.6   33.6    10.8     0.0
          FUEL     (LBS)     1.49   56.1   28.7    15.1     0.1       1.7

ENERGY SUPPLY                                HP-HR
                                             -----
                  (1) ENGINE             =    2.52
                  (2) KINETIC ENERGY     =    0.00
                  (3) POTENTIAL ENERGY   =    0.00
                  (4) ROTATING INERTIA   =    0.00

BREAKDOWN                        PERCENT ENGINE HP-HR
                                 --------------------
                  (1) ACCESSORIES        =    2.29
                  (2) TORQUE CONVERTER   =    0.01
                  (3) CLUTCH             =    0.00
                  (4) GEAR BOX           =    2.00
                  (5) DIFFERENTIAL       =    2.53
                  (6) TIRE SLIP          =    0.00
                              3+4+5+6    =    4.53
                            2+3+4+5+6    =    4.54
                  (7) AERODYNAMIC DRAG   =   56.76
                  (8) ROLLING RESIST     =   29.84
                        SUBTOTAL 1- 8    =   93.83
                  (9) BRAKES             =    4.44
                 (10) ENGINE MOTORING    =    2.09
                        SUBTOTAL 1-10    =  100.36
                 (11) OTHER ENERGY       =    0.00
                           TOTAL 1-11    =  100.36
```

```
VEHICLE PERFORMANCE SIMULATION   18-MAR-81                                              PAGE   4
*************************************************

BREAKDOWN OF % TIME SPENT ON VARIOUS PARTS OF ENGINE MAP

    -20.0   -10.0     0.0    10.0    20.0    30.0    40.0    50.0    60.0    70.0    80.0    90.0   100.0   110.0   120.0
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
  900.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |   0.0 |  -0.4 |   0.5 |   0.0 |   5.2 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |   0.0 |  -2.2 |   2.5 |   0.0 |  26.7 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |    0. | 1021. | 1000. |    0. | 1016. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   0.0 |   0.6 |   0.7 |   0.0 |   0.3 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 1200.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |   0.0 |  -1.1 |   0.2 |   0.0 |   7.3 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |   0.0 |  -4.3 |   0.8 |   0.0 |  28.3 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |    0. | 1339. | 1335. |    0. | 1346. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   0.0 |   0.2 |   0.0 |   0.0 |   0.1 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 1500.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |   0.0 |  -2.1 |   0.2 |   0.0 |   8.8 |   0.0 |  15.9 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |   0.0 |  -6.6 |   0.7 |   0.0 |  28.3 |   0.0 |  47.4 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |    0. | 1696. | 1660. |    0. | 1641. |    0. | 1758. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   0.0 |   0.6 |   0.0 |   0.0 |   0.1 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 1800.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |   0.0 |  -3.1 |   0.6 |   0.0 |   9.8 |   0.0 |  17.7 |  19.1 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |   0.0 |  -8.5 |   1.7 |   0.0 |  25.5 |   0.0 |  47.6 |  51.7 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |    0. | 1545. | 1549. |    0. | 2026. |    0. | 1957. | 1544. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   0.0 |   1.2 |   0.1 |   0.0 |   0.3 |   0.0 |   0.1 |   0.1 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 2100.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |  -4.7 |  -4.0 |   3.6 |   6.9 |  11.0 |  15.6 |  20.6 |  22.8 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | -10.7 |  -9.7 |   8.5 |  16.2 |  25.6 |  35.0 |  47.9 |  51.5 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | 2265. | 2140. | 2224. | 2247. | 2251. | 2345. | 2257. | 2328. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   1.0 |   0.3 |   0.4 |   0.7 |   0.8 |   0.4 |   0.1 |   0.7 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 2400.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |  -6.0 |  -2.7 |   4.0 |   8.4 |  13.2 |  17.3 |  22.9 |  24.6 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | -12.4 |  -5.6 |   8.2 |  17.5 |  27.0 |  35.1 |  45.8 |  51.6 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | 2539. | 2587. | 2587. | 2517. | 2575. | 2585. | 2620. | 2504. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   0.8 |   0.6 |   1.4 |   7.5 |   5.5 |   1.6 |   0.3 |   0.6 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 2700.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |  -7.7 |  -2.4 |   4.6 |   9.5 |  12.3 |  18.8 |  23.8 |  28.4 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | -14.4 |  -4.6 |   8.5 |  17.9 |  22.1 |  35.1 |  43.5 |  52.3 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | 2823. | 2731. | 2657. | 2780. | 2506. | 2817. | 2872. | 2849. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   0.6 |   0.2 |   1.3 |  21.3 |   6.7 |   2.4 |   1.4 |   0.3 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 3000.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |  -9.5 |   0.0 |   5.5 |   9.3 |  13.7 |  19.5 |  25.4 |  30.6 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | -16.1 |   0.0 |   9.4 |  15.6 |  22.6 |  32.7 |  42.4 |  53.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      | 3081. |    0. | 3074. | 3145. | 3164. | 3127. | 3150. | 3034. |    0. |    0. |    0. |    0. |    0. |    0. |
      |   0.2 |   0.0 |   0.8 |   4.3 |  10.3 |   3.0 |   1.0 |   0.1 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
 3300.-+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+-------+
      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
      |   0.0 |   0.0 |   0.0 |  11.0 |  15.3 |  20.6 |  27.6 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |   0.0 |   0.0 |   0.0 |  17.1 |  24.0 |  32.0 |  43.7 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |   0.0 |
      |    0. |    0. |    0. | 3369. | 3343. | 3380. | 3320. |    0. |    0. |    0. |    0. |    0. |    0. |    0. |
```

A directory lets the user know which parts are available. The following example shows the user deleting a part and again adding the same part. A listing of the part is not shown here, but can be listed.

```
 RUN VEHSIM

VEHSIM CAR   06(23) 16-MAR-81   11:22 JOB# 60 TTY062  DSKB  :[04132,402]

*DIR

PART TYPE: SHI

ENTER PART NAME: 5WOT5000

A TOTAL OF     1 SHIFT PARTS ON FILE DSKB  :VSMSLG.BIN[04132,402]

*DEL

PART TYPE: SHI

ENTER NAME OF PART TO BE DROPPED: 5WOT5000

PARTS DELETED FROM VEHSIM PARTS DATA BASE:
DSKB  :VSMSLG.BIN[04132,402]   SHIFT   5WOT5000

PART TYPE:

*@5\5\WOT550.SHI

*SHIFT LOGIC      5WOT5000

END OF VEHSIM CONTROL FILE DSK   :WOT550.SHI[04132,402]

*DUMP

?DUMP ?

*DIALOGUE

*DUMP

DUMP TO TTY?(ANS Y/N) Y

DO YOU WANT A DIRECTORY OF PARTS DUMPED?(ANS Y/N): N

PART TYPE: SHI

ENTER [illegible]000
```

```
.TYP VOLKS.VSM
*OUTPUT       VOLKS.DAT[3,3]
*LIMIT PRINT        OFF
*TITLE        VOLKSWAGON DIESEL STUDY
*USE   VWRB80       VEHICLE
*USE   FSVAG0.048   ENGINE            1       1 2 3 4
*LOCKUP CONVERTER GEAR          1 2 3 4
*USE   EPA4         SHIFT LOGIC
*USE   VWRB805SR    TRANSMISSION
*USE   CCDY1        CONVERTER
*USE   CCCY1        CONVERTER
*USE   LALY1        ACCESSORY
*USE   ZGRADE       ROUTE
*MODIFY             WEIGHT        2375.
*MODIFY             DYNAM        -6.800
*MODIFY             REAR AXLE R   3.900
*MODIFY             DISPLACE      90.00
*MODIFY             C1            .0030
*MODIFY             C2           .00005
*LIMIT PRINT        OFF
*TITLE        BASE LINE CASE WITH URBAN AND HIGHWY
!URBAN AND HIGHWAY ONLY
*LIMIT PRINT        OFF
*USE   URBAN        DRIVING SCHEDULE
*LIMIT PRINT        SEGMENT
*SIMULATE           CAR          DIALOGUE
*LIMIT PRINT        OFF
*USE   EPAHWY       DRIVING SCHEDULE
*LIMIT PRINT        SEGMENT
*SIMULATE           CAR          DIALOGUE
*LIMIT PRINT        OFF
*TITLE        USE TOPSPEED, SHIFT LOGIC=5WOT5000
*USE   5WOT5000     SHIFT LOGIC
*MODIFY             TOPSPEED      1.000
*USE   TOPSPEED     DRIVING SCHEDULE
*LIMIT PRINT        OFF
*LIMIT PRINT        SEC             0.50
*SIMULATE           CAR          DIALOGUE
*LIMIT PRINT        OFF
```

```
TE VOLKS.CTL

[3K Core]
*



HT$$
.RUN COMA:SEND
**,402
*S'T'A'R'T'I'N'G 'S'I'M'U'L'A'T'I'O'N 'O'F VOLKS.VSM
.RUN VEHSIM
*VOLKS
.IF (ERROR) .GOTO DONE4
EXIT
DONE4::
.CLOSE
.RUN COMA:SEND
**,402
*F'I'N'I'S'H'E'D VOLKS.VSM     - 'P'R'I'N'T'I'N'G
.PRINT/DIS:DEL VOLKS.DAT [3,3]
.PRINT/DIS:DEL VOLKS.LOG
*






EX$$

.




SUB/AFTER:18:00:00/TIME:00:25:00 VOLKS
[INP01:VOLKS=/Seq:1554/Time:0:25:00]
```

```
18-Mar-81                                                                                          PAGE    1
                VEHICLE DATA  ( VWRB80     )  $ OLD VEHICLE DATA FORMAT THAT INCLUDES TIRE DATA.
                ----------------------------

VOLKSWAGON RABBIT DIESEL 1980

WEIGHT          =  2375.0   LBS                 AXLE RATIO        =   3.90

FRONTAL AREA    =    20.10  SQ FT               AXLE EFFICIENCY   =   0.97

ROLLING RADIUS  =     0.92  FT

DRAG COEFFICIENT      =   0.400000

                                          CD SENSITIVITY COEFF    =   0.000000

PER WHEEL INERTIA  = 0.500  FT-LB-SEC**2                  C1      =   0.009000

PROPSHAFT INERTIA  = 0.000  FT-LB-SEC**2                  C2      =   0.000050

                NO AXLE SPIN LOSS DATA SPECIFIED                  --------------------------------
```

```
10-Mar-81         ENGINE DATA  ( FBVAGO.048 )                                                                              PAGE    2
                  ---------------------------

                  ENGINE FUEL MAP

CYLINDERS      =    4          FUEL DENSITY       =    7.093  LB/GAL
BORE           =    3.130      ROTATING INERTIA   =    0.030  FT-LB-SEC**2
STROKE         =    2.890
DISPLACEMENT   =   88.9                              MINIMUM    MAXIMUM

10 SPEED POINTS                THROTTLE ANGLE     =    0.00      39.60   DEGREES
                               ENGINE SPEED       = 1000.0     5000.0    RPM
SPEED (RPM) =   700.00
--------------------
   TORQUE(FT-LB)                  0.00    21.60    22.00    22.50    22.90    23.40    23.80    24.30    24.80    25.20
   FUEL RATE(LB/HR)               2.10     2.10     2.10     2.10     2.10     2.20     2.20     2.20     2.20     2.20
   THROTTLE(DEGREES)              0.00     0.00     0.10     0.10     0.20     0.30     0.30     0.40     0.40     0.50
   MANIFOLD VACUUM(IN-HG)         0.40     0.40     0.40     0.50     0.50     0.50     0.50     0.50     0.50     0.50

   TORQUE(FT-LB)                 25.70    26.10    26.60    27.10    27.50    28.00    28.40    28.90    29.40    29.80
   FUEL RATE(LB/HR)               2.30     2.30     2.30     2.30     2.40     2.40     2.40     2.40     2.40     2.50
   THROTTLE(DEGREES)              0.60     0.60     0.70     0.80     0.80     0.90     1.00     1.00     1.10     1.10
   MANIFOLD VACUUM(IN-HG)         0.50     0.50     0.50     0.50     0.50     0.50     0.50     0.50     0.50     0.50

SPEED (RPM) =   800.00
--------------------
   TORQUE(FT-LB)                 -0.70     1.80     2.40     3.00     3.60     4.20     4.80     5.40     6.00     6.60
   FUEL RATE(LB/HR)               2.10     1.00     1.00     1.10     1.10     1.10     1.10     1.10     1.20     1.20
   THROTTLE(DEGREES)              0.00     0.00     0.00     0.00     0.00     0.00     0.10     0.10     0.10     0.20
   MANIFOLD VACUUM(IN-HG)         0.60     0.60     0.60     0.60     0.60     0.60     0.60     0.60     0.60     0.50

   TORQUE(FT-LB)                  7.20     7.90     8.50     9.10     9.70    10.30    10.90    11.50    12.10    42.70
   FUEL RATE(LB/HR)               1.20     1.30     1.30     1.30     1.30     1.40     1.40     1.50     1.50     3.00
   THROTTLE(DEGREES)              0.20     0.30     0.30     0.40     0.50     0.60     0.60     0.70     0.80    39.00
   MANIFOLD VACUUM(IN-HG)         0.50     0.50     0.50     0.50     0.50     0.50     0.50     0.50     0.50     0.60

SPEED (RPM) =  1000.00
--------------------
   TORQUE(FT-LB)                 -2.00     0.29     2.60     5.10     7.50     9.90    12.30    14.80    17.20    19.60
   FUEL RATE(LB/HR)               2.10     1.10     1.20     1.30     1.40     1.60     1.70     1.80     2.00     2.10
   THROTTLE(DEGREES)              4.50     4.50     5.70     6.50     7.10     7.30     7.40     7.60     7.80     8.30
   MANIFOLD VACUUM(IN-HG)         0.70     0.70     0.70     0.70     0.70     0.70     0.70     0.70     0.70     0.70

   TORQUE(FT-LB)                 22.10    24.50    26.90    29.30    31.80    34.20    36.60    39.10    41.50    43.90
   FUEL RATE(LB/HR)               2.30     2.50     2.70     2.80     3.00     3.20     3.40     3.60     3.90     4.10
   THROTTLE(DEGREES)              8.90     9.70    10.40    10.80    10.90    10.70    10.80    12.00    17.20    39.50
   MANIFOLD VACUUM(IN-HG)         0.70     0.70     0.70     0.70     0.70     0.70     0.60     0.60     0.60     0.60

SPEED (RPM) =  1650.00
--------------------
   TORQUE(FT-LB)                 -6.40     0.60     3.40     6.10     8.90    11.70    14.40    17.20    20.00    22.70
   FUEL RATE(LB/HR)               2.10     2.10     2.30     2.40     2.60     2.80     3.10     3.30     3.60     3.90
   THROTTLE(DEGREES)             13.10    13.10    12.40    13.10    14.10    14.50    14.30    13.80    13.40    13.50
   MANIFOLD VACUUM(IN-HG)         1.20     1.20     1.30     1.30     1.30     1.30     1.20     1.10     0.90     0.80

   TORQUE(FT-LB)                 25.50    28.30    31.00    33.80    36.60    39.30    42.10    44.90    47.60    50.40
   FUEL RATE(LB/HR)               4.20     4.50     4.80     5.10     5.50     5.80     6.20     6.60     7.00     7.40
   THROTTLE(DEGREES)             14.20    15.70    17.90    20.30    22.20    22.80    22.20    21.50    23.70    37.60
   MANIFOLD VACUUM(IN-HG)         0.70     0.70     0.70     0.70     0.90     1.10     1.30     1.60     1.80     1.90
```

```
SPEED (RPM) = 2000.00
---------------------
   TORQUE(FT-LB)                 -8.70    1.10    3.90    6.60    9.40   12.20   15.00   17.80   20.60   23.40
   FUEL RATE(LB/HR)               2.10    2.10    2.30    2.60    2.90    3.30    3.70    4.00    4.40    4.70
   THROTTLE(DEGREES)             12.10   12.10   13.00   13.70   14.10   14.40   14.60   14.90   15.30   15.90
   MANIFOLD VACUUM(IN-HG)         1.60    1.60    1.60    1.50    1.50    1.50    1.50    1.50    1.50    1.50

   TORQUE(FT-LB)                 26.10   28.90   31.70   34.50   37.30   40.10   42.90   45.60   48.40   51.20
   FUEL RATE(LB/HR)               5.10    5.50    5.80    6.20    6.60    7.10    7.60    8.20    8.80    9.60
   THROTTLE(DEGREES)             16.60   17.30   17.90   18.40   18.60   18.80   19.30   21.00   25.80   39.30
   MANIFOLD VACUUM(IN-HG)         1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50    1.50

SPEED (RPM) = 2500.00
---------------------
   TORQUE(FT-LB)                -12.00    1.00    3.80    6.60    9.40   12.20   15.00   17.80   20.60   23.40
   FUEL RATE(LB/HR)               2.10    2.80    3.10    3.50    3.90    4.30    4.70    5.20    5.60    6.10
   THROTTLE(DEGREES)             12.50   12.50   13.00   13.90   14.70   15.40   15.90   16.40   16.90   17.40
   MANIFOLD VACUUM(IN-HG)         2.00    2.00    2.10    2.10    2.10    2.10    2.10    2.10    2.00    2.00

   TORQUE(FT-LB)                 26.20   29.00   31.90   34.70   37.50   40.30   43.10   45.90   48.70   51.50
   FUEL RATE(LB/HR)               6.60    7.00    7.50    8.00    8.60    9.20    9.80   10.40   11.20   12.00
   THROTTLE(DEGREES)             17.90   18.60   19.10   19.50   19.80   20.00   20.40   22.00   26.50   39.40
   MANIFOLD VACUUM(IN-HG)         2.00    2.00    2.00    2.00    2.00    2.00    2.00    2.00    1.90    1.90

SPEED (RPM) = 3000.00
---------------------
   TORQUE(FT-LB)                -15.40    1.20    4.10    6.90    9.80   12.70   15.60   18.40   21.30   24.20
   FUEL RATE(LB/HR)               2.10    3.40    3.90    4.40    5.00    5.50    6.10    6.70    7.30    7.80
   THROTTLE(DEGREES)             12.70   12.70   13.40   14.30   15.00   15.70   16.40   17.10   17.90   18.80
   MANIFOLD VACUUM(IN-HG)         2.60    2.60    2.60    2.60    2.60    2.60    2.60    2.60    2.60    2.50

   TORQUE(FT-LB)                 27.10   30.00   32.80   35.70   38.60   41.50   44.30   47.20   50.10   53.00
   FUEL RATE(LB/HR)               8.40    8.90    9.50   10.10   10.80   11.50   12.20   13.10   14.10   15.30
   THROTTLE(DEGREES)             19.80   20.80   21.60   22.20   22.50   22.60   22.90   24.20   28.10   39.40
   MANIFOLD VACUUM(IN-HG)         2.50    2.50    2.50    2.50    2.50    2.50    2.50    2.40    2.40    2.40

SPEED (RPM) = 3500.00
---------------------
   TORQUE(FT-LB)                -18.70    0.80    3.80    6.70    9.70   12.70   15.70   18.60   21.60   24.60
   FUEL RATE(LB/HR)               2.10    4.30    4.90    5.50    6.20    6.80    7.40    8.00    8.70    9.30
   THROTTLE(DEGREES)             13.30   13.30   14.10   15.00   15.90   16.60   17.30   18.10   18.90   19.80
   MANIFOLD VACUUM(IN-HG)         3.20    3.20    3.10    3.10    3.10    3.10    3.10    3.10    3.10    3.10

   TORQUE(FT-LB)                 27.60   30.60   33.50   36.50   39.50   42.50   45.40   48.40   51.40   54.40
   FUEL RATE(LB/HR)              10.00   10.70   11.40   12.10   12.90   13.80   14.60   15.50   16.50   17.50
   THROTTLE(DEGREES)             20.90   22.00   23.10   24.00   24.70   25.30   26.00   27.40   30.80   39.40
   MANIFOLD VACUUM(IN-HG)         3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00    3.00

SPEED (RPM) = 4500.00
---------------------
   TORQUE(FT-LB)                -25.40    0.80    3.50    6.30    9.10   11.80   14.60   17.30   20.10   22.80
   FUEL RATE(LB/HR)               2.10    6.60    7.30    8.00    8.70    9.50   10.20   11.00   11.80   12.60
   THROTTLE(DEGREES)             12.10   12.10   12.90   13.50   14.20   15.10   16.10   17.30   18.60   19.90
   MANIFOLD VACUUM(IN-HG)         4.10    4.10    4.10    4.10    4.10    4.10    4.10    4.10    4.10    4.10

   TORQUE(FT-LB)                 25.60   28.40   31.10   33.90   36.60   39.40   42.10   44.90   47.60   50.40
   FUEL RATE(LB/HR)              13.40   14.30   15.20   16.10   17.10   18.20   19.30   20.50   21.80   23.30
   THROTTLE(DEGREES)             21.00   22.00   22.80   23.30   23.70   24.30   25.40   27.50   31.70   39.60
   MANIFOLD VACUUM(IN-HG)         4.10    4.10    4.10    4.10    4.10    4.00    4.00    4.00    3.90    3.90
```

```
SPEED (RPM) = 5000.00
---------------------
   TORQUE(FT-LB)              -28.80    0.50    3.20    6.00    8.70   11.50   14.20   17.00   19.70   22.50
   FUEL RATE(LB/HR)             2.10    8.40    8.80    9.40   10.10   10.80   11.50   12.30   13.20   14.10
   THROTTLE(DEGREES)            0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
   MANIFOLD VACUUM(IN-HG)       4.40    4.40    4.40    4.40    4.30    4.30    4.30    4.30    4.30    4.30

   TORQUE(FT-LB)               25.20   28.00   30.80   33.50   36.30   39.00   41.80   44.50   47.30   50.00
   FUEL RATE(LB/HR)            15.00   16.10   17.20   18.30   19.60   21.00   22.50   24.10   25.90   27.60
   THROTTLE(DEGREES)            0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00
   MANIFOLD VACUUM(IN-HG)       4.30    4.30    4.30    4.30    4.30    4.30    4.20    4.20    4.20    4.20
```

```
18-Mar-81
                        SHIFT LOGIC  ( EPA4        )
                        ---------------------------

SHIFT LOGIC FOR 4 GEAR TRANSMISSION FOLLOWING EPA TEST PROCEDURE

THIS TRANSMISSION HAS   4  GEARS

UP SHIFT     1 -  2  SHIFT TIME = 0.500 SEC
                     THROTTLE (PCT WOT)        0.00  100.00
                     VEHICLE SPEED (MPH)      15.00   15.00

DOWN SHIFT   2 -  1  SHIFT TIME = 0.500 SEC
                     THROTTLE (PCT WOT)        0.00  100.00
                     VEHICLE SPEED (MPH)      10.00   10.00

UP SHIFT     2 -  3  SHIFT TIME = 0.500 SEC
                     THROTTLE (PCT WOT)        0.00  100.00
                     VEHICLE SPEED (MPH)      25.00   25.00

DOWN SHIFT   3 -  2  SHIFT TIME = 0.500 SEC
                     THROTTLE (PCT WOT)        0.00  100.00
                     VEHICLE SPEED (MPH)      20.00   20.00

UP SHIFT     3 -  4  SHIFT TIME = 0.500 SEC
                     THROTTLE (PCT WOT)        0.00  100.00
                     VEHICLE SPEED (MPH)      40.00   40.00

DOWN SHIFT   4 -  3  SHIFT TIME = 0.500 SEC
                     THROTTLE (PCT WOT)        0.00  100.00
                     VEHICLE SPEED (MPH)      30.00   30.00
```

```
18-Mar-81

                    TRANSMISSION DATA  ( VWRB805SP  )
                    ---------------------------------

VOLKSWAGON RABBIT 5 SPEED, 2 OVERDRIVES

                              1 - G3.45
                              2 - G1.94
                              3 - G1.29
                              4 - G0.97
                              5 - G0.76
```

```
18-Mar-81
                  GEAR DATA  ( G3.45       )
                  --------------------------

NO COMMENT

GEAR RATIO  =  3.450          INPUT INERTIA    =  0.000  FT-LB-SEC**2
EFFICIENCY  =  0.980          OUTPUT INERTIA   =  0.010  FT-LB-SEC**2

                  NO GEAR SPIN LOSS DATA SPECIFIED                ---------------------------------
```

```
18-Mar-81
                  GEAR DATA  ( G1.94       )
                  --------------------------

NO COMMENT

GEAR RATIO  =  1.940          INPUT INERTIA    =  0.000  FT-LB-SEC**2
EFFICIENCY  =  0.980          OUTPUT INERTIA   =  0.010  FT-LB-SEC**2

                  NO GEAR SPIN LOSS DATA SPECIFIED                ---------------------------------
```

```
18-Mar-81
                    GEAR DATA  ( G1.29        )
                    -------------------------

NO COMMENT

GEAR RATIO  =  1.290          INPUT INERTIA    =  0.000  FT-LB-SEC**2
EFFICIENCY  =  0.980          OUTPUT INERTIA   =  0.010  FT-LB-SEC**2

                    NO GEAR SPIN LOSS DATA SPECIFIED             --------------------------------
```

```
18-Mar-81
                    GEAR DATA  ( G0.97        )
                    -------------------------

NO COMMENT

GEAR RATIO  =  0.970          INPUT INERTIA    =  0.000  FT-LB-SEC**2
EFFICIENCY  =  0.980          OUTPUT INERTIA   =  0.010  FT-LB-SEC**2

                    NO GEAR SPIN LOSS DATA SPECIFIED             --------------------------------
```

```
18-Mar-81
                    GEAR DATA  ( G0.76        )
                    -------------------------

NO COMMENT

GEAR RATIO  =  0.760          INPUT INERTIA    =  0.000  FT-LB-SEC**2
EFFICIENCY  =  0.980          OUTPUT INERTIA   =  0.010  FT-LB-SEC**2

                    NO GEAR SPIN LOSS DATA SPECIFIED             --------------------------------
```

```
18-Mar-81

                   DRIVE CONVERTER DATA  ( CODY1       )
                   --------------------------------------

11. INCH DRIVE CONVERTER FOR 1973 250 L6

DIAMETER  =  11.0             PUMP INERTIA      =  0.112  FT-LB-SEC**2

                              TURBINE INERTIA   =  0.053  FT-LB-SEC**2

CONSTANT INPUT TORQUE  =  200.00  LB-FT

SPEED RATIO          0.000     0.100     0.200     0.300     0.400     0.500     0.600     0.700     0.800     0.870
TORQUE RATIO         2.150     2.000     1.850     1.740     1.640     1.500     1.380     1.240     1.100     1.000
INPUT SPEED       1700.000  1745.000  1790.000  1860.000  1925.000  1990.000  2110.000  2230.000  2380.000  2530.000
K-FACTOR             0.000     8.725    18.612    29.912    42.516    57.446    76.204    99.124   128.368   155.641

SPEED RATIO          0.900     0.920     0.940     0.960
TORQUE RATIO         1.000     1.000     1.000     1.000
INPUT SPEED       2785.000  3045.000  3540.000  4150.000
K-FACTOR           177.236   198.089   235.297   281.711
```

```
18-Mar-81

                    COAST CONVERTER DATA  ( COCY1       )
                    ------------------------------------

11. INCH COAST CONVERTER

DIAMETER  =  11.0            PUMP INERTIA     =  0.112  FT-LB-SEC**2

                             TURBINE INERTIA  =  0.053  FT-LB-SEC**2

CONSTANT INPUT TORQUE  =   40.00  LB-FT

SPEED RATIO          3.970     2.584     1.949     1.534     1.377     1.253     1.186     1.147     1.088     1.070
TORQUE RATIO         1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
INPUT SPEED        326.000   520.000   722.000  1006.000  1204.000  1429.000  1650.000  1846.000  2120.000  2400.000

SPEED RATIO          1.053     1.040     1.029     1.024     1.019
TORQUE RATIO         1.000     1.000     1.000     1.000     1.000
INPUT SPEED       2665.000  2916.000  3244.000  3620.000  3980.000
```

```
18-Mar-81

                       ACCESSORY LOSS DATA  ( LALY1       )
                       ------------------------------------

                 ALTERNATOR INPUT LOSSES

                 INERTIA  = 0.001  FT-LB-SEC**2

                       SPEED          TORQUE
                       (RPM)          (LB-FT)
                       -----          -------

                        650.0           1.210
                       1190.0           0.840
                       1830.0           0.600
                       2480.0           0.490
                       3000.0           0.490
```

```
18-Mar-81

                    ROUTE SPECIFICATION  ( ZGRADE      )
                    ----------------------------------------

     500 MILES OF LEVEL ROAD

                   DISTANCE          PERCENT          ROAD          WIND SPEED
     POINT         (MILES)            GRADE        COEFFICIENT        (MPH)
     -----         -------            -----        -----------      ----------

       1           500.000            0.000           1.000           0.000
```

```
18-Mar-81

                    DRIVING SCHEDULE  ( URBAN       )
                    ---------------------------------

FEDERAL TEST PROCEDURE NUMBER 75

INITIAL CONDITIONS          TIME             =  0.00  SEC
                            DISTANCE         =  0.00  FT
                            VEHICLE SPEED    =  0.00  MPH
                            ACCELERATION     =  0.00  FT/SEC**2
                            STARTING GEAR    =  1

SEGMENT             DESIRED PERFORMANCE
-------             -------------------

             ************ SEGMENT TYPE ************           *************** SEGMENT ENDPOINT ***************
                                CONSTANT  ACCEL TO         THROTTLE
SEGMENT     CONSTANT  CONSTANT  PERCENT   AND HOLD  HOLD   RATE OF   RELATIVE  RELATIVE  PASSING   ABSOLUTE  ABSOLUTE  SEGMENT
NUMBER      ACCELER   SPEED     WOT       THROTTLE  GEAR   CHANGE    TIME      DISTANCE  CLEARANCE MILEPOST  VELOCITY  NUMBER

   1                    0.00                                          20.00                                              1
   2          4.50                                                                                          21.00        2
   3                   21.00                                           9.00                                              3
   4         -2.90                                                                                          15.00        4
   5                   15.00                                           5.00                                              5
   6          3.20                                                                                          23.00        6
   7                   23.00                                           5.00                                              7
   8         -3.00                                                                                          16.00        8
   9          0.00                                                     1.00                                              9
  10          3.00                                                                                          25.00       10
  11                   25.00                                          18.00                                             11
  12          0.80                                                                                          30.00       12
  13                   30.00                                          30.00                                             13
  14         -5.00                                                                                           0.00       14
  15                    0.00                                          38.00                                             15
  16          5.00                                                                                          26.00       16
  17                   26.00                                           9.00                                             17
  18         -2.60                                                                                          17.00       18
  19          0.00                                                     1.00                                             19
  20          2.60                                                                                          47.00       20
  21                   47.00                                          12.00                                             21
  22          0.50                                                                                          57.00       22
  23         -0.30                                                                                          51.00       23
  24          0.40                                                                                          56.00       24
  25         -1.30                                                                                          30.00       25
  26         -2.00                                                                                          11.00       26
  27         -5.00                                                                                           0.00       27
  28                    0.00                                          13.00                                             28
  29          5.00                                                                                          20.00       29
  30          1.50                                                                                          36.00       30
  31                   36.00                                          17.00                                             31
  32         -3.50                                                                                          20.00       32
  33         -5.00                                                                                           0.00       33
  34                    0.00                                           5.00                                             34
  35          4.50                                                                                          30.00       35
```

```
          ************ SEGMENT TYPE ************                  *************** SEGMENT ENDPOINT ***************
                              CONSTANT  ACCEL TO        THROTTLE
SEGMENT   CONSTANT  CONSTANT  PERCENT   AND HOLD  HOLD  RATE OF   RELATIVE  RELATIVE  PASSING   ABSOLUTE  ABSOLUTE  SEGMENT
NUMBER    ACCELER   SPEED     WOT       THROTTLE  GEAR  CHANGE    TIME      DISTANCE  CLEARANCE MILEPOST  VELOCITY  NUMBER

  36                30.00                                           4.00                                          36
  37        -4.50                                                                                         0.00  37
  38                 0.00                                          18.00                                          38
  39         4.80                                                                                        26.00  39
  40         2.20                                                                                        36.00  40
  41                36.00                                          31.00                                          41
  42        -3.00                                                                                        20.00  42
  43        -5.00                                                                                         0.00  43
  44                 0.00                                           7.00                                          44
  45         2.50                                                                                        25.00  45
  46                25.00                                          16.00                                          46
  47        -5.00                                                                                         0.00  47
  48                 0.00                                          16.00                                          48
  49         5.00                                                                                        13.00  49
  50         2.50                                                                                        17.00  50
  51                17.00                                          18.00                                          51
  52         0.80                                                                                        27.00  52
  53        -5.00                                                                                         0.00  53
  54                 0.00                                          26.00                                          54
  55         5.00                                                                                        10.00  55
  56         2.50                                                                                        25.00  56
  57                25.00                                          11.00                                          57
  58        -4.00                                                                                         0.00  58
  59                 0.00                                          14.00                                          59
  60         2.00                                                                                        22.00  60
  61                27.00                                          10.00                                          61
  62        -4.00                                                                                         0.00  62
  63         5.00                                                                                        28.00  63
  64                28.00                                          20.00                                          64
  65        -5.00                                                                                         0.00  65
  66         0.00                                                   1.00                                          66
  67         5.00                                                                                        28.00  67
  68                28.00                                          22.00                                          68
  69         1.50                                                                                        33.00  69
  70                33.00                                          10.00                                          70
  71        -1.00                                                                                        30.00  71
  72                30.00                                          12.00                                          72
  73        -1.80                                                                                        19.00  73
  74         0.00                                                   1.00                                          74
  75         1.30                                                                                        26.00  75
  76                26.00                                          97.00                                          76
  77        -4.50                                                                                         0.00  77
  78                 0.00                                           4.00                                          78
  79         5.00                                                                                        28.00  79
  80                28.00                                          12.00                                          80
  81        -1.00                                                                                        23.00  81
  82                23.00                                          28.00                                          82
  83        -5.00                                                                                         0.00  83
  84                 0.00                                          30.00                                          84
  85         5.00                                                                                        17.00  85
  86         2.50                                                                                        27.00  86
  87                27.00                                          10.00                                          87
  88        -2.50                                                                                        15.00  88
```

```
         ************ SEGMENT TYPE ************                 *************** SEGMENT ENDPOINT **************
                            CONSTANT  ACCEL TO        THROTTLE
SEGMENT  CONSTANT  CONSTANT PERCENT   AND HOLD  HOLD  RATE OF   RELATIVE  RELATIVE  PASSING   ABSOLUTE  ABSOLUTE  SEGMENT
NUMBER   ACCELER   SPEED    WOT       THROTTLE  GEAR  CHANGE    TIME      DISTANCE  CLEARANCE MILEPOST  VELOCITY  NUMBER


   89       -1.00                                                                                            0.00     89
   90        2.00                                                                                           15.00     90
   91        0.60                                                                                           26.00     91
   92                 26.00                                         15.00                                             92
   93       -2.00                                                                                           20.00     93
   94       -5.00                                                                                            0.00     94
   95                  0.00                                         15.00                                             95
   96        5.00                                                                                           23.00     96
   97                 23.00                                          5.00                                             97
   98       -5.00                                                                                            0.00     98
   99                  0.00                                         10.00                                             99
  100        5.00                                                                                           13.00    100
  101                 13.00                                          6.00                                            101
  102        2.00                                                                                           21.00    102
  103                 21.00                                         20.00                                            103
  104       -3.00                                                                                            0.00    104
  105                  0.00                                          8.00                                            105
  106        3.00                                                                                           10.00    106
  107                 10.00                                          7.00                                            107
  108        3.00                                                                                           25.00    108
  109                 25.00                                         28.00                                            109
  110       -5.00                                                                                            0.00    110
  111                  0.00                                         25.00                                            111
  112        3.50                                                                                           20.00    112
  113                 20.00                                         12.00                                            113
  114       -3.00                                                                                            0.00    114
  115                  0.00                                          5.00                                            115
  VEHSIM CAR    06(23) STATUS REPORT
  ------------------------------------
BATCH MODE      /PTY
SIMULATION MODE-CAR  /DYNAMOMETER
RUN TITLE-BASE LINE CASE WITH URBAN AND HIGHWY
ENGINE(1)-F8VAG0.048
DRIVE CONVERTER-CODY1
COAST CONVERTER-COCY1
VEHICLE-VWRB80
TRANSMISSION - VWRB805SP
GEAR # 1-G3.45       ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 2-G1.94       ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 3-G1.29       ASSIGNED TO ENGINE-F8VAG0.048
GEAR # 4-G0.97       ASSIGNED TO ENGINE-F8VAG0.048
ACCESSORY #  1-LALY1
DRIVING SCHEDULE-URBAN
SHIFT LOGIC-EPA4
ROUTE-$DYNO
TIRE-$VEHICLE
GEARS LOCKED UP-  1  2  3  4
NO GEARS UNLOCKED
LIMIT PRINT-SEGME  0.0000000E+00
DEBUG-OFF    0.0000000E+00  0.0000000E+00
TTY OUTPUT-OFF
LPT OUTPUT-ON
C1    MODIFIED FROM  .9000E-02 TO  .9000E-02
C2    MODIFIED FROM  .5000E-04 TO  .5000E-04
REAR  MODIFIED FROM  3.900     TO  3.900
WEIGH MODIFIED FROM  2375.     TO  2375.
DISPL MODIFIED FROM  88.95     TO  90.00
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18-Mar-81                      VEHICLE PERFORMANCE SIMULATION                        PAGE   1
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                    RUN TITLE ( BASE LINE CASE WITH URBAN AND HIGHWY                          )
                    --------------------------------------------------------------------------

                       DRIVING SCHEDULE ( URBAN      )        USING ROUTE ( $DYNO      )
                       ------------------------------         --------------------------

                                 INST          CUM                                                                         DRS         GRADE-
   SEC.   MILES    MPH    ACC     MPG   BSFC   MPG GEAR     RDLD     HPW      HPE   RPM   TORQ    VAC    SR   ETA PCT.WOT   SEG BRAKES ABILITY
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   0.00   0.000    0.0   0.00    0.00   2.53   0.0   1      0.0     0.0      0.5 1000.     3.    0.7 1.000 1.000     10.     1    0.0    0.00
  20.00   0.000    0.0   0.00    0.00   2.53   0.0   1      0.0     0.0      0.5 1000.     3.    0.7 1.000 1.000     10.     1    0.0    0.00
  27.44   0.022   21.0   4.50   13.11   0.49   8.3   2      2.1    21.5     23.4 2418.    51.    1.8 1.000 1.000     98.     2    0.0   15.09
  36.44   0.075   21.0   0.00   46.45   1.31  19.6   2      2.1     2.1      2.5 2418.     5.    2.0 1.000 1.000     27.     3    0.0********
  39.47   0.090   15.0  -2.90   50.07  99.99  22.1   2      1.3    -2.2     -2.3 1727.    -7.    1.3 1.000 1.000      0.     4  126.5********
  44.47   0.111   15.0   0.00   44.69   1.55  24.4   2      1.3     1.3      1.5 1727.     5.    1.4 1.000 1.000     20.     5    0.0********
  48.14   0.130   23.0   3.20   17.60   0.49  23.2   2      2.5    17.5     19.1 2648.    38.    2.1 1.000 1.000     78.     6    0.0   10.67
  53.14   0.162   23.0   0.00   44.92   1.28  25.7   2      2.5     2.5      2.8 2648.     6.    2.2 1.000 1.000     29.     7    0.0********
  56.56   0.181   16.0  -3.00   53.41  99.99  27.4   2      1.4    -2.5     -2.7 1842.    -8.    1.4 1.000 1.000      0.     8  127.7********
  57.56   0.185   16.0   0.00   47.31   1.44  27.6   2      1.4     1.4      1.7 1842.     5.    1.4 1.000 1.000     21.     9    0.0********
  61.96   0.210   25.0   3.00   18.15   0.49  26.2   2      2.8    18.2     19.8 2878.    36.    2.4 1.000 1.000     75.    10    0.0   10.00
  79.96   0.335   25.0   0.00   63.49   0.88  33.5   3      2.8     2.8      3.2 1914.     9.    1.5 1.000 1.000     28.    11    0.0********
  89.13   0.405   30.0   0.80   40.04   0.56  34.6   3      3.9     8.8      9.5 2297.    22.    1.8 1.000 1.000     52.    12    0.0    2.60
 119.13   0.655   30.0   0.00   59.31   0.83  41.1   3      3.9     3.9      4.3 2297.    10.    1.9 1.000 1.000     33.    13    0.0********
 128.68   0.695    0.0  -3.21    0.00  99.99  41.5   1      0.0     0.0     -0.4 1000.    -2.    0.7 1.000 1.000      0.    14  302.3    0.00
 166.68   0.695    0.0   0.00    0.00   2.53  37.5   1      0.0     0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    15    0.0    0.00
 175.93   0.732   26.0   2.88   19.10   0.49  34.5   3      3.0    18.3     19.6 1991.    52.    1.5 1.000 1.000    100.    16    0.0    9.40
 184.93   0.797   26.0   0.00   64.29   0.84  35.9   3      3.0     3.0      3.4 1991.     9.    1.5 1.000 1.000     29.    17    0.0********
 190.29   0.829   17.0  -2.60   56.74  99.99  36.6   2      1.5    -3.0     -3.2 1957.    -9.    1.6 1.000 1.000      0.    18   92.4********
 191.29   0.833   17.0   0.00   49.76   1.34  36.6   2      1.5     1.5      1.8 1957.     5.    1.5 1.000 1.000     22.    19    0.0********
 211.37   1.019   47.0   1.70   24.80   0.50  33.0   4      9.2    25.4     27.1 2706.    53.    2.1 1.000 1.000    100.    20    0.0    5.49
 223.37   1.175   47.0   0.00   55.11   0.61  34.9   4      9.2     9.2      9.9 2706.    19.    2.3 1.000 1.000     50.    21    0.0********
 252.70   1.599   57.0   0.50   37.97   0.51  36.1   4     13.7    19.5     20.9 3281.    33.    2.8 1.000 1.000     71.    22    0.0    1.61
 282.04   2.039   51.0  -0.30   61.76   0.70  39.4   4     10.9     7.8      8.4 2936.    15.    2.5 1.000 1.000     44.    23    0.0********
 300.37   2.312   56.0   0.40   40.12   0.52  39.6   4     13.2    17.8     19.0 3224.    31.    2.7 1.000 1.000     67.    24    0.0    1.29
 329.70   2.662   30.0  -1.30  100.14  99.99  43.4   4      3.9    -2.3     -2.3 1727.    -7.    1.3 1.000 1.000      0.    25   19.7********
 344.17   2.745   11.0  -2.00   36.72  99.99  43.9   2      0.8    -1.0     -0.9 1266.    -4.    0.9 1.000 1.000      0.    26   85.9********
 347.82   2.751    0.0  -4.35    0.00  99.99  43.8   1      0.0     0.0     -0.4 1000.    -2.    0.7 1.000 1.000      0.    27  302.3    0.00
 360.82   2.751    0.0   0.00    0.00   2.53  43.4   1      0.0     0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    28    0.0    0.00
 367.35   2.770   20.0   4.63   12.72   0.49  42.6   2      2.0    20.9     22.7 2303.    52.    1.7 1.000 1.000    100.    29    0.0   15.52
 383.71   2.897   36.0   1.50   28.77   0.50  41.9   3      5.5    16.5     17.7 2756.    34.    2.3 1.000 1.000     71.    30    0.0    4.88
 400.71   3.067   36.0   0.00   53.39   0.80  42.4   3      5.5     5.5      6.0 2756.    11.    2.4 1.000 1.000     38.    31    0.0********
 407.42   3.119   20.0  -3.50   60.76  99.99  42.8   3      2.0    -1.6     -1.7 1531.    -6.    1.1 1.000 1.000      0.    32  184.9********
 414.02   3.138    0.0  -4.88    0.00  99.99  42.7   1      0.0     0.0     -0.4 1000.    -2.    0.7 1.000 1.000      0.    33  302.3    0.00
 419.02   3.138    0.0   0.00    0.00   2.53  42.6   1      0.0     0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    34    0.0    0.00
 430.94   3.193   30.0   2.81   19.22   0.49  41.3   3      3.9    21.1     22.6 2297.    52.    1.7 1.000 1.000    100.    35    0.0    9.17
 434.94   3.226   30.0   0.00   59.31   0.83  41.5   3      3.9     3.9      4.3 2297.    10.    1.9 1.000 1.000     33.    36    0.0********
 445.49   3.270    0.0  -0.22    0.00   4.79  41.6   1      0.0     0.0      0.2 1000.     1.    0.7 1.000 1.000      7.    37  266.3    0.00
 463.49   3.270    0.0   0.00    0.00   2.53  41.1   1      0.0     0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    38    0.0    0.00
 472.95   3.307   26.0   2.88   19.10   0.49  40.2   3      3.0    18.3     19.6 1991.    52.    1.5 1.000 1.000    100.    39    0.0    9.40
 479.61   3.365   36.0   2.20   22.93   0.48  39.8   3      5.5    21.6     23.2 2756.    44.    2.3 1.000 1.000     87.    40    0.0    7.17
 510.61   3.675   36.0   0.00   53.39   0.80  40.6   3      5.5     5.5      6.0 2756.    11.    2.4 1.000 1.000     38.    41    0.0********
 518.44   3.736   20.0  -3.00   60.76  99.99  41.0   3      2.0    -1.6     -1.7 1531.    -6.    1.1 1.000 1.000      0.    42  149.3********
 525.04   3.755    0.0  -4.88    0.00  99.99  41.0   1      0.0     0.0     -0.4 1000.    -2.    0.7 1.000 1.000      0.    43  302.3    0.00
 532.04   3.755    0.0   0.00    0.00   2.53  40.8   1      0.0     0.0      0.5 1000.     3.    0.7 1.000 1.000     10.    44    0.0    0.00
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                        RUN TITLE ( BASE LINE CASE WITH URBAN AND HIGHWY                                        )
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                           DRIVING SCHEDULE ( URBAN        )          USING ROUTE ( $DYNO        )
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                           INST          CUM                                                                           DRS          GRADE-
   SEC.    MILES    MPH   ACC     MPG   BSFC   MPG GEAR    RDLD    HPW    HPE   RPM  TORQ    VAC    SR    ETA PCT.WOT SEG BRAKES ABILITY
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  547.27   3.808   25.0  2.50  20.29   0.51 40.2   2     2.8    15.6   17.1 2878.   31.    2.4 1.000 1.000   67.    45    0.0     8.32
  563.27   3.989   25.0  0.00  63.49   0.88 40.6   3     2.8     2.8    3.2 1914.    9.    1.5 1.000 1.000   28.    46    0.0*********
  571.37   3.947    0.0 -1.55   0.00  99.99 40.6   1     0.0     0.0   -0.4 1000.   -2.    0.7 1.000 1.000    0.    47  302.3     0.00
  587.37   3.947    0.0  0.00   0.00   2.53 40.3   1     0.0     0.0    0.5 1000.    3.    0.7 1.000 1.000   10.    48    0.0     0.00
  591.19   3.954   13.0  5.00  11.07   0.50 40.1   1     1.0    14.6   16.8 2662.   33.    2.2 1.000 1.000   70.    49    0.0    18.13
  594.10   3.966   17.0  2.50  21.76   0.49 40.0   2     1.5    10.2   11.2 1957.   30.    1.4 1.000 1.000   64.    50    0.0     8.32
  612.10   4.051   17.0  0.00  49.76   1.34 40.1   2     1.5     1.5    1.8 1957.    5.    1.5 1.000 1.000   22.    51    0.0*********
  631.22   4.169   27.0  0.80  41.24   0.56 40.0   3     3.2     7.6    8.3 2067.   21.    1.6 1.000 1.000   50.    52    0.0     2.60
  639.92   4.202    0.0 -0.23   0.00   5.01 40.0   1     0.0     0.0    0.2 1000.    1.    0.7 1.000 1.000    7.    53  302.3     0.00
  665.92   4.202    0.0  0.00   0.00   2.53 39.6   1     0.0     0.0    0.5 1000.    3.    0.7 1.000 1.000   10.    54    0.0     0.00
  668.86   4.206   10.0  5.00  11.52   0.48 39.4   1     0.7    11.2   12.8 2047.   33.    1.5 1.000 1.000   69.    55    0.0    18.13
  678.23   4.251   25.0  2.50  20.29   0.51 39.1   2     2.8    15.6   17.1 2878.   31.    2.4 1.000 1.000   67.    56    0.0     8.32
  689.23   4.327   25.0  0.00  63.49   0.88 39.3   3     2.8     2.8    3.2 1914.    9.    1.5 1.000 1.000   28.    57    0.0*********
  699.13   4.362    0.0 -2.55   0.00  99.99 39.3   1     0.0     0.0   -0.4 1000.   -2.    0.7 1.000 1.000    0.    58  230.3     0.00
  713.13   4.362    0.0  0.00   0.00   2.53 39.1   1     0.0     0.0    0.5 1000.    3.    0.7 1.000 1.000   10.    59    0.0     0.00
  729.85   4.414   22.0  2.00  23.54   0.54 38.7   2     2.3    11.3   12.4 2533.   26.    2.0 1.000 1.000   59.    60    0.0     6.65
  739.85   4.475   22.0  0.00  45.61   1.30 38.8   2     2.3     2.3    2.6 2533.    5.    2.1 1.000 1.000   28.    61    0.0*********
  748.25   4.500    0.0 -2.77   0.00  99.99 38.8   1     0.0     0.0   -0.4 1000.   -2.    0.7 1.000 1.000    0.    62  230.3     0.00
  758.53   4.545   28.0  2.83  19.24   0.49 38.1   3     3.4    19.6   21.1 2144.   52.    1.6 1.000 1.000  100.    63    0.0     9.25
  778.53   4.700   28.0  0.00  61.80   0.84 38.6   3     3.4     3.4    3.8 2144.    9.    1.7 1.000 1.000   31.    64    0.0*********
  787.48   4.735    0.0 -4.53   0.00  99.99 38.7   1     0.0     0.0   -0.4 1000.   -2.    0.7 1.000 1.000    0.    65  302.3     0.00
  788.48   4.735    0.0  0.00   0.00   2.53 38.7   1     0.0     0.0    0.5 1000.    3.    0.7 1.000 1.000   10.    66    0.0     0.00
  798.76   4.780   28.0  2.83  19.24   0.49 38.1   3     3.4    19.6   21.1 2144.   52.    1.6 1.000 1.000  100.    67    0.0     9.25
  820.76   4.951   28.0  0.00  61.80   0.84 38.6   3     3.4     3.4    3.8 2144.    9.    1.7 1.000 1.000   31.    68    0.0*********
  825.65   4.993   33.0  1.50  29.99   0.49 38.5   3     4.6    14.7   15.8 2526.   33.    2.0 1.000 1.000   70.    69    0.0     4.88
  835.65   5.084   33.0  0.00  56.25   0.81 38.7   3     4.6     4.6    5.1 2526.   11.    2.1 1.000 1.000   36.    70    0.0*********
  840.05   5.123   30.0 -1.00  90.43  99.99 38.9   3     3.9    -2.2   -2.2 2297.   -5.    1.8 1.000 1.000    9.    71    0.0*********
  852.05   5.223   30.0  0.00  59.31   0.83 39.1   3     3.9     3.9    4.3 2297.   10.    1.9 1.000 1.000   33.    72    0.0*********
  861.26   5.285   19.0 -1.80  63.42  99.99 39.4   2     1.8    -4.0   -4.2 2188.  -10.    1.8 1.000 1.000    0.    73   21.6*********
  862.26   5.290   19.0  0.00  48.52   1.31 39.4   2     1.8     1.8    2.1 2188.    5.    1.8 1.000 1.000   24.    74    0.0*********
  870.77   5.344   26.0  1.30  34.11   0.50 39.3   3     3.0     9.9   10.7 1991.   28.    1.5 1.000 1.000   61.    75    0.0     4.23
  967.77   6.044   26.0  0.00  64.29   0.84 41.1   3     3.0     3.0    3.4 1991.    9.    1.5 1.000 1.000   29.    76    0.0*********
  976.97   6.078    0.0 -4.39   0.00  99.99 41.1   1     0.0    -0.0   -0.4 1000.   -2.    0.7 1.000 1.000    0.    77  266.3*********
  980.97   6.078    0.0  0.00   0.00   2.53 41.1   1     0.0     0.0    0.5 1000.    3.    0.7 1.000 1.000   10.    78    0.0     0.00
  991.25   6.123   28.0  2.83  19.24   0.49 40.6   3     3.4    19.6   21.1 2144.   52.    1.6 1.000 1.000  100.    79    0.0     9.25
 1003.25   6.216   28.0  0.00  61.80   0.84 40.8   3     3.4     3.4    3.8 2144.    9.    1.7 1.000 1.000   31.    80    0.0*********
 1010.58   6.268   23.0 -1.00  76.77  99.99 40.9   3     2.5    -2.2   -2.2 1761.   -7.    1.3 1.000 1.000    1.    81    0.0*********
 1038.58   6.447   23.0  0.00  61.48   0.95 41.3   3     2.5     2.5    2.8 1761.    8.    1.4 1.000 1.000   27.    82    0.0*********
 1046.08   6.471    0.0 -2.88   0.00  99.99 41.3   1     0.0     0.0   -0.4 1000.   -2.    0.7 1.000 1.000    0.    83  302.3     0.00
 1076.08   6.471    0.0  0.00   0.00   2.53 40.9   1     0.0     0.0    0.5 1000.    3.    0.7 1.000 1.000   10.    84    0.0     0.00
 1081.66   6.486   17.0  4.63  12.85   0.49 40.7   2     1.5    17.6   19.2 1957.   52.    1.6 1.000 1.000  100.    85    0.0    15.52
 1088.18   6.526   27.0  2.50  22.16   0.47 40.5   3     3.2    17.0   18.3 2067.   46.    1.6 1.000 1.000   91.    86    0.0     8.15
 1098.18   6.601   27.0  0.00  63.13   0.84 40.7   3     3.2     3.2    3.6 2067.    9.    1.6 1.000 1.000   30.    87    0.0*********
 1105.50   6.644   15.0 -2.50  50.07  99.99 40.8   2     1.3    -2.2   -2.3 1727.   -7.    1.3 1.000 1.000    0.    88   97.5*********
 1127.80   6.690    0.0 -0.70   0.00  99.99 40.6   1     0.0     0.0   -0.3 1000.   -1.    0.7 1.000 1.000    1.    89   14.1     0.00
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                         RUN TITLE ( BASE LINE CASE WITH URBAN AND HIGHWY                                    )
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                           DRIVING SCHEDULE ( URBAN      )          USING ROUTE ( $DYNO        )
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                               INST        CUM                                                                  DRS        GRADE-
   SEC.    MILES   MPH   ACC    MPG  BSFC  MPG GEAR    RDLD     HPW     HPE  RPM  TORQ   VAC    SR    ETA PCT.WOT SEG BRAKES ABILITY
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 1138.80   6.713  15.0  2.00  17.23  0.71 40.4   1      1.3     7.5     8.7 3071.   15.   2.7 1.000 1.000   44.   90   0.0    7.13
 1167.36   6.876  26.0  0.60  45.91  0.59 40.4   3      3.0     6.2     6.8 1991.   18.   1.5 1.000 1.000   44.   91   0.0    1.95
 1182.36   6.984  26.0  0.00  64.29  0.84 40.6   3      3.0     3.0     3.4 1991.    9.   1.5 1.000 1.000   29.   92   0.0*********
 1186.76   7.012  20.0 -2.00  66.76 99.99 40.7   3      2.0    -1.7    -1.7 1531.   -6.   1.1 1.000 1.000    0.   93  78.3*********
 1193.36   7.031   0.0 -4.88   0.00 99.99 40.7   1      0.0     0.0    -0.4 1000.   -2.   0.7 1.000 1.000    0.   94 302.3    0.00
 1208.36   7.031   0.0  0.00   0.00  2.53 40.5   1      0.0     0.0     0.5 1000.    3.   0.7 1.000 1.000   10.   95   0.0    0.00
 1215.83   7.056  23.0  4.65  12.48  0.49 40.2   2      2.5    24.4    26.5 2648.   53.   2.0 1.000 1.000  100.   96   0.0   15.60
 1220.83   7.088  23.0  0.00  44.92  1.28 40.2   2      2.5     2.5     2.8 2648.    6.   2.2 1.000 1.000   29.   97   0.0*********
 1227.98   7.110   0.0 -1.73   0.00 99.99 40.2   1      0.0     0.0    -0.4 1000.   -2.   0.7 1.000 1.000    0.   98 302.3    0.00
 1237.98   7.110   0.0  0.00   0.00  2.53 40.1   1      0.0     0.0     0.5 1000.    3.   0.7 1.000 1.000   10.   99   0.0    0.00
 1241.80   7.117  13.0  5.00  11.07  0.50 40.0   1      1.0    14.6    16.8 2662.   33.   2.2 1.000 1.000   70.  100   0.0   18.13
 1247.80   7.139  13.0  0.00  28.59  2.42 39.9   1      1.0     1.0     1.3 2662.    3.   2.2 1.000 1.000   24.  101   0.0*********
 1254.25   7.169  21.0  2.00  23.81  0.53 39.8   2      2.1    10.7    11.7 2418.   26.   1.9 1.000 1.000   58.  102   0.0    6.65
 1274.25   7.286  21.0  0.00  46.45  1.31 39.9   2      2.1     2.1     2.5 2418.    5.   2.0 1.000 1.000   27.  103   0.0*********
 1284.85   7.317   0.0 -1.43   0.00 99.99 39.9   1      0.0     0.0    -0.4 1000.   -2.   0.7 1.000 1.000    0.  104 158.2    0.00
 1292.85   7.317   0.0  0.00   0.00  2.53 39.8   1      0.0     0.0     0.5 1000.    3.   0.7 1.000 1.000   10.  105   0.0    0.00
 1297.74   7.323  10.0  3.00  15.56  0.56 39.7   1      0.7     7.0     8.1 2047.   21.   1.5 1.000 1.000   49.  106   0.0   10.76
 1304.74   7.343  10.0  0.00  30.86  2.34 39.7   1      0.7     0.7     1.0 2047.    3.   1.6 1.000 1.000   19.  107   0.0*********
 1312.63   7.381  25.0  3.00  18.15  0.49 39.4   2      2.8    18.2    19.8 2878.   36.   2.4 1.000 1.000   75.  108   0.0   10.00
 1340.63   7.575  25.0  0.00  63.49  0.88 39.8   3      2.8     2.8     3.2 1914.    9.   1.5 1.000 1.000   28.  109   0.0*********
 1348.73   7.604   0.0 -1.55   0.00 99.99 39.8   1      0.0     0.0    -0.4 1000.   -2.   0.7 1.000 1.000    0.  110 302.3    0.00
 1373.73   7.604   0.0  0.00   0.00  2.53 39.6   1      0.0     0.0     0.5 1000.    3.   0.7 1.000 1.000   10.  111   0.0    0.00
 1382.66   7.629  20.0  3.50  16.82  0.47 39.4   2      2.0    16.3    17.8 2303.   41.   1.8 1.000 1.000   82.  112   0.0   11.68
 1394.66   7.696  20.0  0.00  47.43  1.31 39.4   2      2.0     2.0     2.3 2303.    5.   1.9 1.000 1.000   26.  113   0.0*********
 1404.76   7.724   0.0 -2.09   0.00 99.99 39.4   1      0.0     0.0    -0.4 1000.   -2.   0.7 1.000 1.000    0.  114 158.2    0.00
 1409.76   7.724   0.0  0.00   0.00  2.53 39.3   1      0.0     0.0     0.5 1000.    3.   0.7 1.000 1.000   10.  115   0.0    0.00
```

```
SHIFT FREQUENCY DATA BY GEAR                          18-Mar-81                  PAGE   4
----------------------------                                                     --------

 TOTAL SHIFTS  =    70    SHIFTS PER MILE  =   9.1    NUMB GEARS  =  4

 GEAR INTO     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20

 UPSHIFTS      0 18 16  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

 DOWNSHIFTS   18 16  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0




GEAR TIME DISTRIBUTION
----------------------

TRANSMISSION: VWRB805SP          GEARS LOCKED UP:    1   2   3   4

 NO.         NAME:        RATIO:       %TIME:
----     ----------   ----------   ----------
   1     G3.45             3.450        32.05
   2     G1.94             1.940        21.73
   3     G1.29             1.290        37.36
   4     G0.97             0.970         8.86
   5     G0.76             0.760         0.00
```

```
VEHICLE PERFORMANCE SIMULATION   18-Mar-81                                        PAGE  5
*******************************************

RUN TITLE = BASE LINE CASE WITH URBAN AND HIGHWY

SCHEDULE AVERAGES     FUEL ECONOMY       = 39.34 MPG
                      WORK PER MILE      =  0.24 HP-HR/MI
                      AVG SP FUEL CONS =  0.76 LBS/HP-HR
                      AVG SPEED          = 19.7  MPH

ADDITIONAL RUN DATA

  DRIVING SCHEDULE NAME = URBAN         ROUTE NAME               = $DYNO         (  6.8)
  VEHICLE NAME          = VWRU80        ENGINE NAME              = F0VAGO.048
  CONVERTER NAME        = COCY1         SHIFT LOGIC NAME         = EPA4
  WEIGHT (LBS)          =   2375.       STROKE (INCHES)          =   2.89
  DISPLACEMENT (CU IN)  =    90.0       REAR AXLE RATIO          =   3.90
  WIND VELOCITY (MPH)   =     0.0       FUEL DENSITY (LB/GAL) =   7.09
  AERO DRAG  = 20.10 , 0.40             TIRES  =    9.00 , 0.05 , 1.00
                                         N/V    =  45.10

TOTALS                     TOTAL        PERCENT OF TOTAL
        VARIABLE (UNITS) AMOUNT (CRUISE ACCEL  DECEL   IDLE ) (BRAKES)
        -------- ------- ------  ------ ------ ------ ------  ------
        TIME     (SECS) 1409.8    35.7   24.4   21.8   18.1
        DISTANCE (MILES)    7.7   47.8   28.1   24.1    0.0
        ENERGY   (HP-HR)   1.82   28.0   65.6    4.5    1.9
        FUEL     (LBS)     1.39   32.7   45.0   16.1    6.2      9.5

ENERGY SUPPLY                               HP-HR
                                            -----
                  (1) ENGINE            =    1.82
                  (2) KINETIC ENERGY    =    0.00
                  (3) POTENTIAL ENERGY =    0.00
                  (4) ROTATING INERTIA =    0.00

BREAKDOWN                         PERCENT ENGINE HP-HR
                                  --------------------
                  (1) ACCESSORIES       =    4.69
                  (2) TORQUE CONVERTER =    0.06
                  (3) CLUTCH            =    0.02
                  (4) GEAR BOX          =    2.05
                  (5) DIFFERENTIAL      =    2.98
                  (6) TIRE SLIP         =    0.00
                            3+4+5+6     =    5.05
                          2+3+4+5+6     =    5.11
                  (7) AERODYNAMIC DRAG =   28.91
                  (8) ROLLING RESIST    =   28.20
                        SUBTOTAL 1- 8   =   66.92
                  (9) BRAKES            =   24.07
                 (10) ENGINE MOTORING   =    9.69
                        SUBTOTAL 1-10   =  100.68
                 (11) OTHER ENERGY      =    0.00
                           TOTAL 1-11   =  100.68
```

```
VEHICLE PERFORMANCE SIMULATION    18-Mar-81                           PAGE   6
********************************************

BREAKDOWN OF % TIME SPENT ON VARIOUS PARTS OF ENGINE MAP

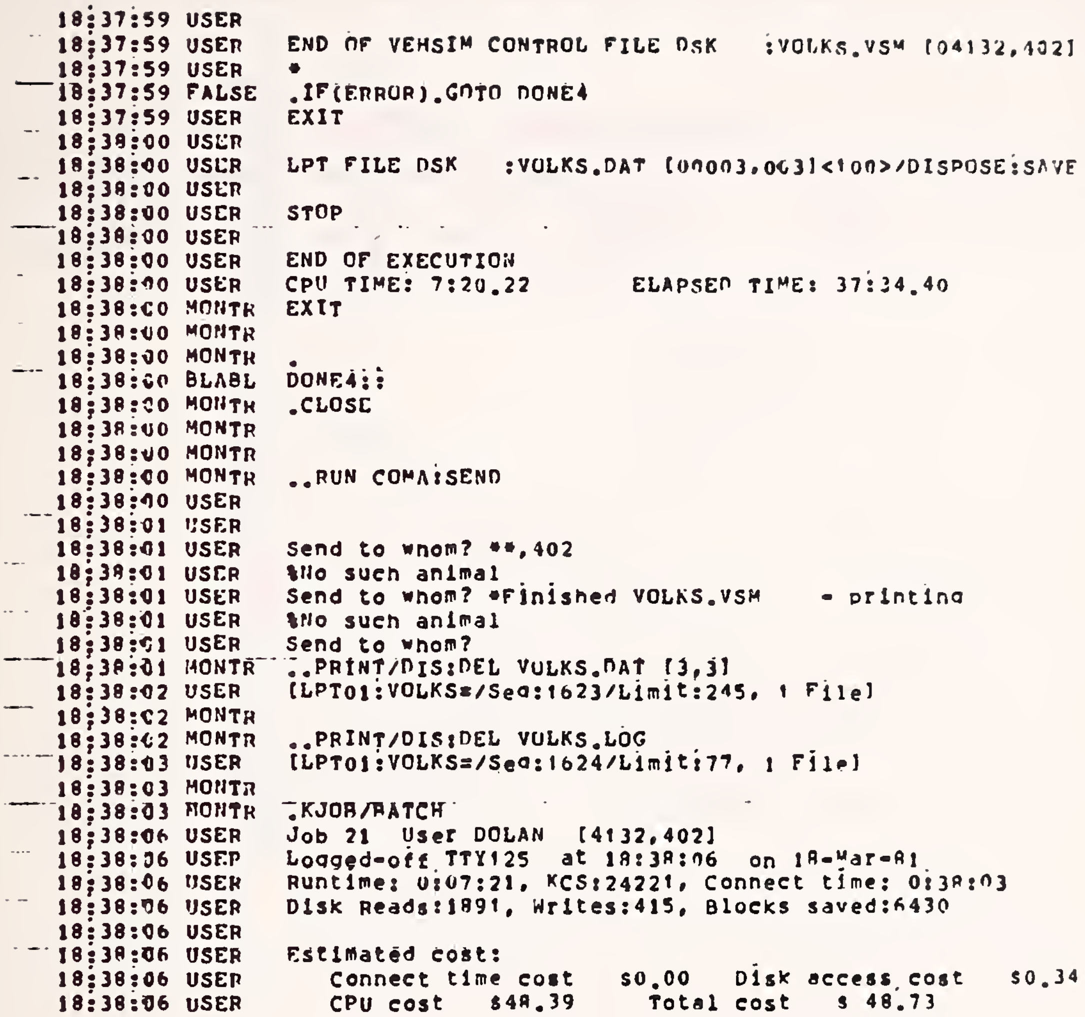
    -20.0    -10.0      0.0     10.0     20.0     30.0     40.0     50.0     60.0     70.0     80.0     90.0    100.0    110.0    120.0
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
 900.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !    0.0 !   -0.4 !    0.5 !    3.0 !    5.1 !    6.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !    0.0 !   -2.2 !    2.5 !   15.6 !   26.2 !   31.1 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !     0. !  1030. !  1000. !  1013. !  1019. !  1020. !     0. !     0. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    0.0 !    3.3 !   18.1 !    1.0 !    0.6 !    1.2 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
1200.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !    0.0 !   -1.1 !    0.2 !    4.0 !    6.5 !    8.4 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !    0.0 !   -4.4 !    0.8 !   15.6 !   25.4 !   32.9 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !     0. !  1353. !  1351. !  1346. !  1352. !  1343. !     0. !     0. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    0.0 !    2.1 !    0.1 !    0.2 !    0.2 !    0.3 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
1500.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !    0.0 !   -2.0 !    2.3 !    4.4 !    8.6 !   10.5 !   13.6 !   17.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !    0.0 !   -6.4 !    6.8 !   13.8 !   26.6 !   33.4 !   40.0 !   50.8 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !     0. !  1660. !  1745. !  1689. !  1704. !  1657. !  1779. !  1757. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    0.0 !    4.1 !    2.7 !    0.3 !    0.3 !    0.4 !    0.0 !    0.2 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
1800.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !    0.0 !   -3.0 !    3.1 !    5.1 !    8.8 !   12.2 !   16.8 !   19.2 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !    0.0 !   -8.1 !    8.2 !   13.6 !   23.5 !   32.6 !   44.3 !   51.5 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !     0. !  1941. !  1968. !  1963. !  1966. !  1972. !  1990. !  1964. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    0.0 !    4.6 !   16.6 !    1.0 !    1.2 !    1.1 !    0.4 !    1.1 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
2100.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !   -4.6 !   -3.7 !    3.8 !    5.9 !   10.0 !   14.0 !   19.0 !   22.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !  -10.6 !   -8.9 !    9.0 !   13.7 !   23.5 !   32.5 !   44.5 !   51.6 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !  2263. !  2197. !  2223. !  2256. !  2236. !  2253. !  2245. !  2243. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    1.4 !    1.3 !    8.1 !    1.2 !    0.8 !    1.5 !    0.4 !    0.8 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
2400.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !   -6.0 !   -3.1 !    2.4 !    6.3 !   11.0 !   15.9 !   22.4 !   25.3 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !  -12.4 !   -6.5 !    5.1 !   13.0 !   22.9 !   32.9 !   46.2 !   52.1 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !  2539. !  2525. !  2507. !  2542. !  2528. !  2542. !  2550. !  2546. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    0.6 !    0.6 !    3.9 !    2.0 !    0.4 !    1.4 !    0.3 !    0.7 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
2700.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !   -7.5 !   -2.8 !    3.2 !    7.1 !   15.0 !   17.2 !   23.7 !   27.9 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !  -14.1 !   -5.2 !    5.9 !   13.5 !   27.7 !   31.7 !   45.7 !   51.9 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !  2790. !  2850. !  2878. !  2773. !  2840. !  2857. !  2725. !  2822. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    0.2 !    0.4 !    0.0 !    5.7 !    0.9 !    1.4 !    0.1 !    0.4 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
3000.-+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+--------+
      !        !        !        !        !        !        !        !        !        !        !        !        !        !        !
      !    0.0 !   -1.9 !    3.8 !    9.9 !   16.9 !   19.0 !    0.0 !   29.5 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !    0.0 !   -3.3 !    6.4 !   16.6 !   29.2 !   31.7 !    0.0 !   51.1 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
      !     0. !  3112. !  3075. !  3134. !  3046. !  3140. !     0. !  3035. !     0. !     0. !     0. !     0. !     0. !     0. !
      !    0.0 !    0.3 !    0.0 !    1.8 !    0.5 !    1.7 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !    0.0 !
3300.-------------------------------------------------------------------------------------------------------------------------------
```

3.5 LOG FILE

```
18:00:01 BAJOB  BATCON version 102(2067) running VOLKS sequence 1554 in stream 4
18:00:01 BAFIL  Input from DSKB:VOLKS.CTL[4132,402]
18:00:01 BAFIL  Output to  DSKB:VOLKS.LOG[4132,402]
18:00:01 BASUM  Job parameters
                Time:00:25:00   Unique:YES   Restart:NO   Output:LOG

18:00:01 MONTR
18:00:02 MONTR  .LOGIN 4132/402 /DEFER/SPOOL:ALL/TIME:1500/LOCATE:1/NAME:"DOLAN"
18:00:02 USER   JOB 21 TSC DECsystem10A v8 TTY125
18:00:06 USER   18:00   18-Mar-81       Wed
18:00:07 MONTR
18:00:07 MONTR  ..RUN COMA:SEND
18:00:09 USER
18:00:11 USER
18:00:11 USER   Send to whom? **,402
18:00:11 USER   %No such animal
18:00:11 USER   Send to whom? *Starting simulation of VOLKS.VSM
18:00:11 USER   %No such animal
18:00:11 USER   Send to whom?
18:00:20 MONTR  ..RUN VEHSIM
18:00:20 USER
18:00:26 USER
18:00:26 USER   VEHSIM CAR   06(23) 18-Mar-81   18:00 JOB# 21 TTY125  DSKB  :[04132,402]
18:00:26 USER   *@VOLKS
18:00:28 USER
18:00:28 USER   *OUTPUT     VOLKS.DAT[3,3]
18:00:31 USER
18:00:31 USER   LPT FILE DSKB  :021VSM.DAT[04132,402]<100>/DISPOSE:SAVE
18:00:32 USER
18:00:32 USER   *LIMIT PRINT      OFF
18:00:32 USER   *TITLE      VOLKSWAGON DIESEL STUDY
18:00:32 USER   *USE  VWRB80      VEHICLE
18:00:36 USER   *USE  F9VAG0.048  ENGINE          1       1 2 3 4
18:01:06 USER   *LOCKUP CONVERTER GEAR          1 2 3 4
18:01:06 USER   *USE  EPA4        SHIFT LOGIC
18:01:11 USER   *USE  VWRB805SP   TRANSMISSION
18:01:23 USER   *USE  CODY1       CONVERTER
18:01:26 USER   *USE  COCY1       CONVERTER
18:01:26 USER   *USE  LALY1       ACCESSORY
18:01:27 USER   *USE  ZGRADE      ROUTE
18:01:31 USER   *MODIFY           WEIGHT        2375.
18:01:31 USER   *MODIFY           DYNAM        -6.800
18:01:31 USER   *MODIFY           REAR AXLE R   3.900
18:01:31 USER   *MODIFY           DISPLACE      90.00
18:01:35 USER   *MODIFY           C1            .0090
18:01:35 USER   *MODIFY           C2           .00005
18:01:35 USER   *LIMIT PRINT      OFF
18:01:36 USER   *TITLE      BASE LINE CASE WITH URBAN AND HIGHWY
18:01:36 USER   !URBAN AND HIGHWAY ONLY
18:01:36 USER   *LIMIT PRINT      OFF
18:01:36 USER   *USE  URBAN       DRIVING SCHEDULE
18:01:44 USER   [DSK-DRS/NSEC:  2/NSEG:  50]
18:01:47 USER   [DSK-DRS/NSEC:  3/NSEG:  15/LAST SECTION]
18:01:51 USER   *LIMIT PRINT      SEGMENT
18:01:51 USER   *SIMULATE         CAR          DIALOGUE
18:01:51 USER
18:01:51 USER   [SIMULATING]
18:01:51 USER   [REACHED INITIAL CONDITIONS]
18:01:52 USER   FSEG:  1 CUMT:   20.00 CUMD:   0.000 MPH:  0.0 CPUS:  0.00 CPUT:    0.06
18:01:58 USER
```

```
18:09:16 USER
18:09:16 USER          VEHICLE PERFORMANCE SIMULATION    18-Mar-81                                    PAGE   7
18:09:16 USER          ***************************************************
18:09:16 USER
18:09:16 USER
18:09:16 USER   RUN TITLE = BASE LINE CASE WITH URBAN AND HIGHWY
18:09:16 USER
18:09:16 USER   SCHEDULE AVERAGES       FUEL ECONOMY       = 39.34 MPG
18:09:16 USER                           WORK PER MILE      =  0.24 HP-HR/MI
18:09:16 USER                           AVG SP FUEL CONS =  0.76 LBS/HP-HR
18:09:16 USER                           AVG SPEED          = 19.7  MPH
18:09:16 USER
18:09:16 USER
18:09:16 USER   ADDITIONAL RUN DATA
18:09:16 USER
18:09:16 USER     DRIVING SCHEDULE NAME = URBAN          ROUTE NAME                 = $DYNO          (   6.8)
18:09:17 USER     VEHICLE NAME          = VWRBBO         ENGINE NAME                = F8VAG0.048
18:09:17 USER     CONVERTER NAME        = COCY1          SHIFT LOGIC NAME           = EPA4
18:09:17 USER     WEIGHT (LBS)          =  2375.         STROKE (INCHES)            =   2.89
18:09:18 USER     DISPLACEMENT (CU IN)  =    90.0        REAR AXLE RATIO            =   3.90
18:09:18 USER     WIND VELOCITY (MPH)   =     0.0        FUEL DENSITY (LB/GAL) =   7.09
18:09:18 USER     AERO DRAG  = 20.10 , 0.40              TIRES  =    9.00 , 0.05 , 1.00
18:09:18 USER                                             N/V    =  45.10
18:09:19 USER
18:09:19 USER
18:09:19 USER   TOTALS                        TOTAL          PERCENT OF TOTAL
18:09:19 USER           VARIABLE (UNITS) AMOUNT (CRUISE ACCEL  DECEL   IDLE ) (BRAKES)
18:09:19 USER           -------- ------- ------  ------ ------ ------ ------   ------
18:09:19 USER           TIME     (SECS) 1409.8    35.7   24.4   21.8   18.1
18:09:19 USER           DISTANCE (MILES)   7.7    47.8   28.1   24.1    0.0
18:09:19 USER           ENERGY   (HP-HR)   1.82   28.0   65.6    4.5    1.9
18:09:19 USER           FUEL     (LBS)     1.39   32.7   45.0   16.1    6.2      9.5
18:09:19 USER
18:09:19 USER
18:09:19 USER   ENERGY SUPPLY                              HP-HR
18:09:19 USER                                              -----
18:09:19 USER                       (1) ENGINE             =    1.82
18:09:19 USER                       (2) KINETIC ENERGY     =    0.00
18:09:19 USER                       (3) POTENTIAL ENERGY =    0.00
18:09:19 USER                       (4) ROTATING INERTIA =    0.00
18:09:19 USER
18:09:19 USER
18:09:19 USER   BREAKDOWN                        PERCENT ENGINE HP-HP
18:09:19 USER                                    --------------------
18:09:19 USER                       (1) ACCESSORIES        =   4.69
18:09:19 USER                       (2) TORQUE CONVERTER =   0.06
18:09:19 USER                       (3) CLUTCH             =   0.02
18:09:19 USER                       (4) GEAR BOX           =   2.05
18:09:19 USER                       (5) DIFFERENTIAL   ,   =   2.98
18:09:19 USER                       (6) TIRE SLIP          =   0.00
18:09:19 USER                                 3+4+5+6  =   5.05
18:09:19 USER                               2+3+4+5+6  =   5.11
18:09:19 USER                       (7) AERODYNAMIC DRAG =  28.91
18:09:19 USER                       (8) ROLLING RESIST     =  28.20
18:09:19 USER                             SUBTOTAL 1- 8  =  66.92
18:09:19 USER                       (9) BRAKES             =  24.07
18:09:19 USER                      (10) ENGINE MOTORING    =   9.69
18:09:19 USER                             SUBTOTAL 1-10  = 100.68
18:09:19 USER                      (11) OTHER ENERGY       =   0.00
18:09:19 USER                                TOTAL 1-11  = 100.68
18:09:19 USER   *LIMIT PRINT       OFF
```



```
18:37:59 USER
18:37:59 USER   END OF VEHSIM CONTROL FILE DSK   :VOLKS.VSM [04132,402]
18:37:59 USER   *
18:37:59 FALSE  .IF(ERROR).GOTO DONE4
18:37:59 USER   EXIT
18:38:00 USER
18:38:00 USER   LPT FILE DSK   :VOLKS.DAT [00003,003]<100>/DISPOSE:SAVE
18:38:00 USER
18:38:00 USER   STOP
18:38:00 USER
18:38:00 USER   END OF EXECUTION
18:38:00 USER   CPU TIME: 7:20.22       ELAPSED TIME: 37:34.40
18:38:00 MONTR  EXIT
18:38:00 MONTR
18:38:00 MONTR  .
18:38:00 BLABL  DONE4::
18:38:00 MONTR  .CLOSE
18:38:00 MONTR
18:38:00 MONTR
18:38:00 MONTR  ..RUN COMA:SEND
18:38:00 USER
18:38:01 USER
18:38:01 USER   Send to whom? **,402
18:38:01 USER   %No such animal
18:38:01 USER   Send to whom? *Finished VOLKS.VSM    - printing
18:38:01 USER   %No such animal
18:38:01 USER   Send to whom?
18:38:01 MONTR  ..PRINT/DIS:DEL VOLKS.DAT [3,3]
18:38:02 USER   [LPT01:VOLKS=/Seq:1623/Limit:245, 1 File]
18:38:02 MONTR
18:38:02 MONTR  ..PRINT/DIS:DEL VOLKS.LOG
18:38:03 USER   [LPT01:VOLKS=/Seq:1624/Limit:77, 1 File]
18:38:03 MONTR
18:38:03 MONTR  .KJOB/BATCH
18:38:06 USER   Job 21  User DOLAN  [4132,402]
18:38:06 USER   Logged-off TTY125  at 18:38:06  on 18-Mar-81
18:38:06 USER   Runtime: 0:07:21, KCS:24221, Connect time: 0:38:03
18:38:06 USER   Disk Reads:1891, Writes:415, Blocks saved:6430
18:38:06 USER
18:38:06 USER   Estimated cost:
18:38:06 USER      Connect time cost   $0.00   Disk access cost   $0.34
18:38:06 USER      CPU cost   $48.39     Total cost   $ 48.73
```

3.6 SCAN PROGRAM

The most time consuming aspect for completing VEHSIM batch runs has been the requirement that the input commands be in exact card image formats because the VEHSIM control files were originally intended to be key punched from prepared forms as shown in section 5.2.

For this reason a utility program SCAN was created to accept free-format VEHSIM command lines and transform them into VEHSIM compatible control files. A sample SCAN file is shown below.

```
↑C

.TYP VOLKS.SCN
=VOLKS.VSM
*OUTPUT            VOLKS.DAT[3*3]
*LIMIT PRINT OFF
*TITLE VOLKSWAGON DIESEL STUDY
*USE VWRB80           VEHICLE
*USE FSVAG0.048        ENGINE     1  1  2  3  4
*LOCKUP CONVERTER GEARS     1  2  3  4
*USE EPA4           SHIFT LOGIC
*USE VWRB805SR             TRANSMISSION
*USE CODY1                 CONVERTER
*USE CDCY1                 CONVERTER
*USE LALY1                 ACCESSORY
*USE ZGRADE                ROUTE
*MODIFY WEIGHT             2375.
*MOD DYNO                  -6.90
*MODIFY REAR AXLE RATIO             3.90
*MODIFY DISPLACEMENT            97.
*MODIFY C1             0.009
*MODIFY C2             0.00005
*LIMIT PRINT OFF
*TITLE BASE LINE CASE WITH URBAN AND HIGHWY
$URMDH
*TITLE USE TOPSPEED, SHIFT LOGIC=SWOT5000
*USE SWOT5000             SHIFT LOGIC
*MODIFY TOPSPEED             1.00
*USE TOPSPEED              DRIVING SCHEDULE
$TEST

.$.
```

4. VEHICLE SYSTEMS INTEGRATION

In order to simulate an entire vehicle system correctly it is necessary to select the vehicle parts which combine to represent an actual vehicle. This procedure, known as vehicle systems integration, involves scanning the VEHSIM parts file and matching the "VEHSIM part" to the actual vehicle system part. If the part is not available the user must apply discretion in determining the part nearest to the actual vehicle system part. In addition, the user must then determine how this part integrates into the entire vehicle system.

Once the user is satisfied with the parts selection, a VEHSIM request form (Figure 4-1) should be completed to insure that all the parts necessary to form a vehicle have been selected. Also, modifications to these parts can be made at the bottom of the request form. A description of each of the parts is provided below to facilitate the user's selection of vehicle parts.

VEHICLE

The vehicle contains basic characteristics that describe the vehicle such as weight, frontal area, tire rolling radius, aerodynamic drag coefficient, axle ratio, axle efficiency, wheel inertia, propshaft inertia, and rolling resistance coefficients. The weight of the vehicle should be selected based on the drive schedule. For example, the weight of a light duty truck should be GVWR (gross vehicle weight rating) for a performance schedule and (IW) inertia weight for the EPA fuel economy schedules.

The INERTIA weight (IW = CURB ± 300 lb) class for the EPA schedules can be determined from Table 4-1. The aerodynamic drag characteristics of the vehicle can be determined from a number of sources. The EPA lists dynamometer horsepower at 50 mph for aerodynamic loading. The frontal areas of vehicles can usually be obtained from manufacturer's specifications or from the MVMA (Motor Vehicle Manufacturers Association) specifications form.

VEHSIM CAR REQUEST

Requested by: ____________________ Date: __________

Priority is: ___Same Day ___Night ___Slow

The VEHSIM control file (.VSM) is:

= ____________________ Total no. of simulations ____

*OUTPUT ______________.DAT[3,3] Total no. of pages ____

*LIMIT PRINT OFF

*TITLE ______________________________

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ VEHICLE

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ TIRE (Optional)

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ ENGINE 1 1 2 3 4 5

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ TRANSMISSION

*LOCKUP CONVERTER GEARS ____________

*UNLOCK CONVERTER GEARS ____________

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ SHIFT LOGIC

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ CONVERTER (Coast)

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ CONVERTER (Drive)

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ ACCESSORY

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ ACCESSORY

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ ROUTE

*USE ☐☐☐☐☐☐☐☐☐☐ ____________ DRIVE SCHEDULE

*MODIFY ____________ ____________

*MODIFY ____________ ____________

*MODIFY ____________ ____________

*LIMIT PRINT ____________ ____________

*SIMULATE CAR DIALOGUE

FIGURE 4-1. VEHSIM REQUEST

TABLE 4-1. INERTIA WEIGHT CLASSES

INERTIA WEIGHT	INERTIA WEIGHT CLASS (LBS)	
	1979 AND EARLIER	1980 AND BEYOND
UP TO 1062	1000	1000
1063 - 1187	1000	1125
1188 - 1312	1250	1250
1313 - 1437	1250	1375
1438 - 1562	1500	1500
1563 - 1687	1500	1625
1688 - 1812	1750	1750
1813 - 1937	1750	1875
1938 - 2062	2000	2000
2063 - 2187	2000	2125
2188 - 2312	2250	2250
2313 - 2437	2250	2375
2438 - 2562	2500	2500
2563 - 2687	2500	2625
2688 - 2812	2750	2750
2813 - 2937	2750	2875
2938 - 3062	3000	3000
3063 - 3187	3000	3125
3188 - 3312	3000	3250
3313 - 3437	3500	3375
3438 - 3562	3500	3500
3563 - 3687	3500	3625
3688 - 3812	3500	3750
3813 - 3937	4000	3875
3938 - 4125	4000	4000
4126 - 4375	4000	4250
4376 - 4625	4500	4500
4626 - 4875	4500	4750
4876 - 5125	5000	5000
5126 - 5375	5000	5250
5376 - 5750	5500	5500

TABLE 4-1. INERTIA WEIGHT CLASSES (CONT)

INERTIA WEIGHT	INERTIA WEIGHT CLASS (LBS)	
	1979 AND EARLIER	1980 AND BEYOND
5751 - 6250	6000	6000
6251 - 6750	6500	6500
6751 - 7250	7000	7000
7251 - 7750	7500	7500
7751 - 8250	8000	8000
8251 - 8750	8500	8500
8751 - 9250	9000	9000
9251 - 9750	9500	9500
9751 - 10,000	10,000	10,000

The drag coefficient can be obtained from coast down tests based on aerodynamic loading at 50 mph by

$$C_D = HP/0.81 * (Af)$$

where: C_D = Aerodynamic drag coefficient

Hp = Aerodynamic horsepower at 50 mph

Af = Frontal Area (ft^2).

The tire characteristics are generally supplied by the tire manufacturers. The N/V ratio (rpm/mph) can be compared with the EPA* descriptions by $\frac{N}{V} = \left[\frac{14.0}{RR}\right] * AR * GR$

where: RR = Rolling radius (ft)

AR = Axle ratio

GR = Gear ratio (top).

To obtain valid fuel economy results, the tire manufacturers' N/V ratios should be consistent with the EPA data. A sample of rolling resistance values is shown in Table 4-2, and the rolling radius (effectively N/V) can be found in the MVMA specifications form in terms of rev/mile at 45 mph.

TIRES

The tires are generally considered to be part of the vehicle file. However, there may be situations during a tire study where it is easier to change the tire file rather than change the vehicle file. This occurs, when changing the rolling radius of the tires. The coefficients C_1 and C_2 are rolling resistance coefficients. A second order equation is used to approximate the rolling resistance force which can be made linear by setting C_2 to zero. A tire efficiency term is a multiplicative factor which can be used to adjust for tire slip.

---

*EPA 1980 Gas Mileage Guide, United States Environmental Protection Agency, Ann Arbor MI.

TABLE 4-2. TIRE IDENTIFICATION AND TEST DATA LIGHT TRUCK TIRES

Test Number	Tire Number UMLT	Tire Description (All LT Tires)	Construction	Manufacturer	Serial Number	Cold Inflation Press. psi	Equil. Infla. Press. psi	Radial Load lb	Meas. Equil. Rolling Resis. lb	Equivalent Equil. Rolling Resistance on Highway lb	Coeff. of Rolling Resist. lb/1000 lb.
1	1	7.50-16D	6N	Firestone	VAWYCMM309	60	68.1	1930	23.2	19.1	.0099
2	1	7.50-16D	6N	Firestone	VAWYCMM309	40	51.7	1930	27.5	22.6	.0117
3	1	7.50-16D	6N	Firestone	VAWYCMM309	50	58.9	1460	18.6	15.3	.0105
4	1	7.50-16D	6N	Firestone	VAWYCMM309	60	75.5	2440	28.8	23.7	.0097
5	11	9.50R16.50	1s+4s	Michelin	ZUE869191	65	71.9	2190	17.9	14.9	.0068
6	11	9.50R16.50	1s+4s	Michelin	ZUE869191	45	52.7	2190	19.8	16.5	.0075
7	11	9.50R16.50	1s+4s	Michelin	ZUE869191	55	63.1	1670	15.2	12.6	.0075
8	11	9.50R16.50	1s+4s	Michelin	ZUE869191	65	76.1	2780	22.1	18.4	.0066
9	25	7.50-16D	-	Goodyear	MDWYCM0489	60	69.4	1930	21.8	17.9	.0093
10	25	7.50-16D	-	Goodyear	MDWYCM0489	40	50.9	1930	26.8	22.0	.0114
11	28	9.50R16.50	2p+(2s+2N)	Dunlop	OAXL8A7158	65	75.2	2190	21.8	18.9	.0082
12	28	9.50R16.50	2p+(2s+2N)	Dunlop	OAXL8A7158	45	55.9	2190	22.3	18.5	.0084
13	5	8.00-16.50	6N	Firestone	VJXJOPM349	60	71.5	1610	17.7	14.8	.0092
14	5	8.00-16.50	6N	Firestone	VJXJDPM349	40	52.2	1610	20.5	17.2	.0107
15	23	8.00-16.50	4N+2N	Goodyear	MEXJOP0509	60	67.4	1610	17.3	14.5	.0090
16	23	8.00-16.50	4N+2N	Goodyear	MEXJOP0509	40	50.2	1610	19.6	16.5	.0102
17	4	8.75-16.5E	6N	Firestone	VOXKOUN399	75	86.0	2240	23.0	19.2	.0086
18	4	8.75-16.5E	6N	Firestone	VOXKOUN399	55	72.2	2240	27.3	22.7	.0101
19	19	8.75-16.5E	4N+2N	Goodyear	MEXKOU1379	75	82.8	2240	21.4	17.9	.0080
20	19	8.75-16.5E	4N+2N	Goodyear	MEXKOU1379	55	66.2	2240	24.1	20.1	.0090
21	3	9.50-16.50	6N	Firestone	VJXLOPM268	60	68.8	2190	22.9	18.9	.0086
22	3	9.50-16.50	6N	Firestone	VJXLDPM268	40	52.4	2190	28.4	23.5	.0107
23	26	9.50-16.50				60		2190			
24	26	9.50-16.50				40		2190			
25	6	9.50-16.5E	6N	Firestone	VJXLOUM409	75	84.7	2650	28.2	23.4	.0098
26	6	9.50-16.5E	6N	Firestone	VJKXOUM409	55	72.1	2650	30.4	25.1	.0095
27	22	9.50-16.5E	4N+2N	Goodyear	MFXLOU1159	75	85.4	2650	25.4	21.0	.0079
28	22	9.50-16.5E	4N+2N	Goodyear	MFXLOU1159	55	69.0	2650	27.5	22.8	.0086
29	10	10-15B	4p	Dunlop	OAAN457398	30	36.1	1390	21.6	18.0	.0129

SOURCE: Rolling Resistance of Light Truck Tires, S.K. Clark, University of Michigan. DOT-TSC-1031.

ENGINE

The engine is the most important part of a vehicle system when determining fuel economy. The engine, for simulation purposes, is represented by a compilation of steady state engine test data, commonly termed an "engine map." These engine maps are obtained from engine dynamometer test facilities such as those at the Bartlesville Energy Technology Center. The maps usually consist of 20 load points for each of 10-15 speed points with about 40 individual measurements at each condition, which include fuel consumption, emissions, spark advance, air-fuel ratio, back pressure, and ambient conditions. The load points are torque and manifold vacuum, and the throttle angle may also be included to accommodate certain shift logics based on engine throttle angle. To produce an engine map, processing and display programs are usually required because of the voluminous data involved. Such programs are in use at the Transportation Systems Center for processing engine data from TSC's Automotive Research Laboratory.* All the engine maps available for use in the VEHSIM program are updated annually** and the format of the engine maps to be input to VEHSIM can be seen in reduced form.***

Engine maps may also be provided by the automobile manufacturers. These maps usually are provided in graphical form, as shown in Figure 4-2. The required format for VEHSIM necessitates a negative torque for each engine speed and if this point is not given it must be extrapolated. For proper simulation it is extremely important that all the data are consistent. For example, a negative torque should occur at a closed throttle angle and torques should uniformly increase for increasing throttle angle.

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*Colello, Ralph G., "Processing and Display Programs for Steady State Engine Test Data," Transportation Systems Center, Report No. PM-T-51, December 1975.

**Kidd, James A. and Rogowicz, Joseph J., "Engine Catalog and Performance Analysis," Transportation Systems Center, Report No. DOT-TSC-NHTSA-79-39, March 1980.

***Kidd, James A. and Colello, Ralph G, "A Compilation of Steady State Automotive Engine Test Data," Transportation Systems Center, Report No. DOT-TSC-NHTSA-78-40, September 1978.

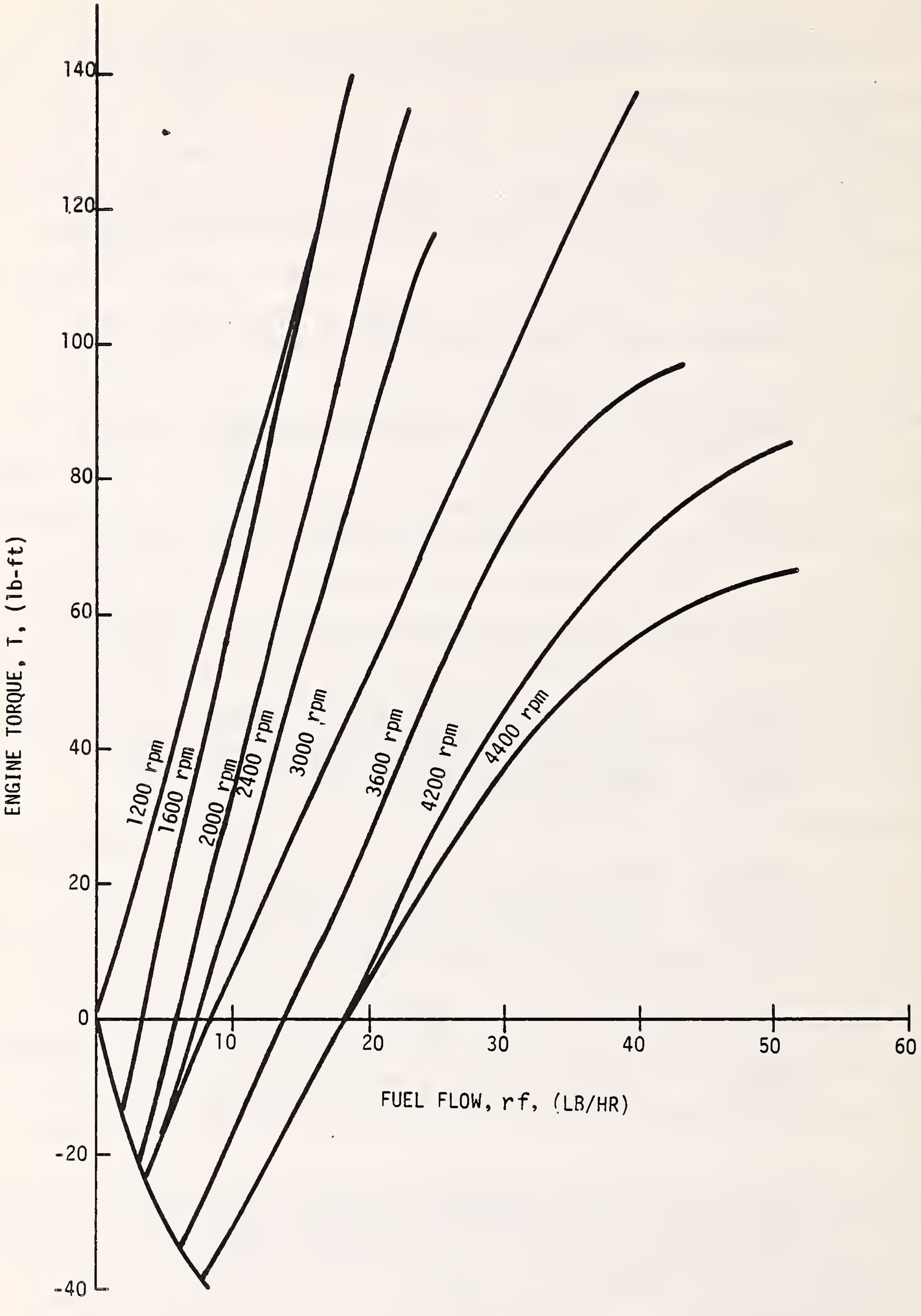

FIGURE 4-2. ENGINE FUEL FLOW FOR 1981 PRODUCTION ENGINE

In some engine tests, wide open throttle cannot always be achieved at idle or low rpm conditions. Therefore, the wide open throttle load point at idle should be extrapolated from the WOT torque curve. Also, when receiving maps in this format, the user should be aware of the test parameters such as fuel octane rating, intake restrictions and accessory loading, since variations in these parameters may sometimes produce different fuel rates for identical engines.

Exhaust gas emission simulation (not recommended except for NO_x) is provided for by using the above mentioned preferred units in the engine data card, by using a fuel specific gravity of 0.1198, and by entering emissions data (gm/hr) in the FUEL RATE data fields. The results of a simulation will produce the inverse of the sought after gm/mi emissions, and show this inverse as the fuel economy in the summary sheet.

GEAR-TRANSMISSION

Gears must be loaded into the parts data file separately. The gear input inertia includes the rotational inertia of the input shaft and attached drive gear while output inertia is the rotational inertia of the specified gear. The gear efficiencies are usually in the range of 96-98 percent.

The transmission part is simply a list of gears used in the transmission. The gears listed must either be already in the data base as individual gear parts, or loaded as gear parts along with the transmission. The transmission part may contain a maximum of 20 gears. Once the transmission part and gears are loaded into the data base, all the gears used in the transmission are entered collectively as the transmission part during a simulation. This eliminates the string of gears to be typed in during interactive simulation. The feature of modifying a gear in the transmission still remains functional through the USE command.

SHIFT LOGIC

The shift logic is the operating control strategy for the entire vehicle system. The logic for a manual transmission is fixed by the EPA for 3, 4 and 5 speed gearboxes as shown in Table 4-3.

TABLE 4-3. EPA SHIFT LOGIC

Shift	Vehicle Speed (mph)
1-2	15
2-3	25
3-4	40
4-5	50
2-1	10
3-2	20
4-3	35
5-4	45

The shift logic for an automatic transmission is more complicated and can be presented in a variety of approaches. Each shift logic is tailored for a specific vehicle-engine combination and is presented in terms of shift lines for a given engine load and speed (vehicle, engine or propshaft) as shown in Figures 4-3 and 4-4. Using a shift logic not designated for a particular vehicle, or modifying vehicle parameters for a given shift logic may produce erroneous results or cause a simulation to be terminated. Because the automatic shift logic relies on the engine map for a load setting, the engine should be checked for compatability with the shift logic. For problems associated with the shift logic, a debug may help in solving a shift related problem.

CONVERTER

Since most coast converter curves are identical, the drive converter is the critical converter element to simulate. Converter curves are provided in a variety of ways including those

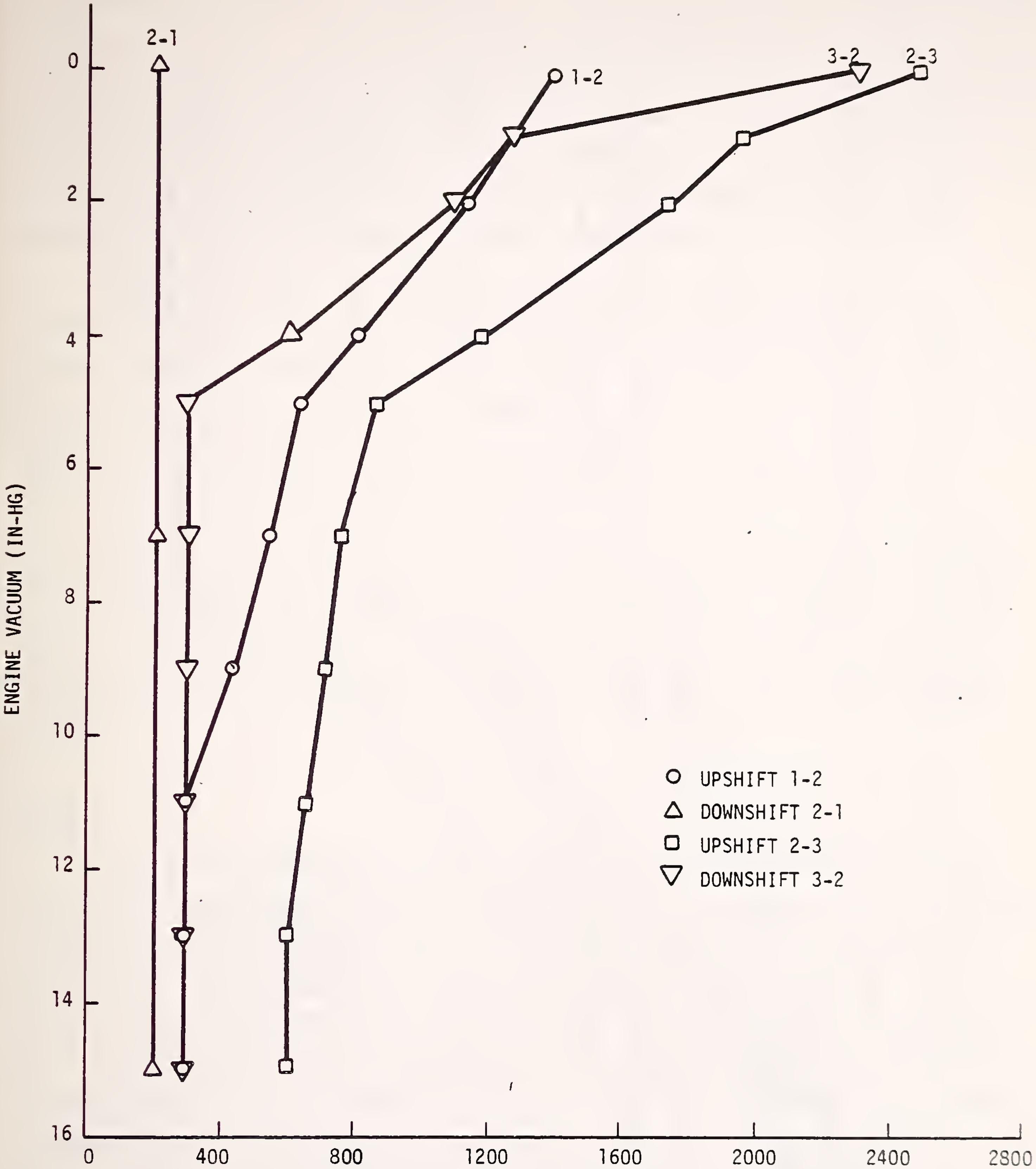

FIGURE 4-3. SAMPLE SHIFT LOGIC USING VACUUM

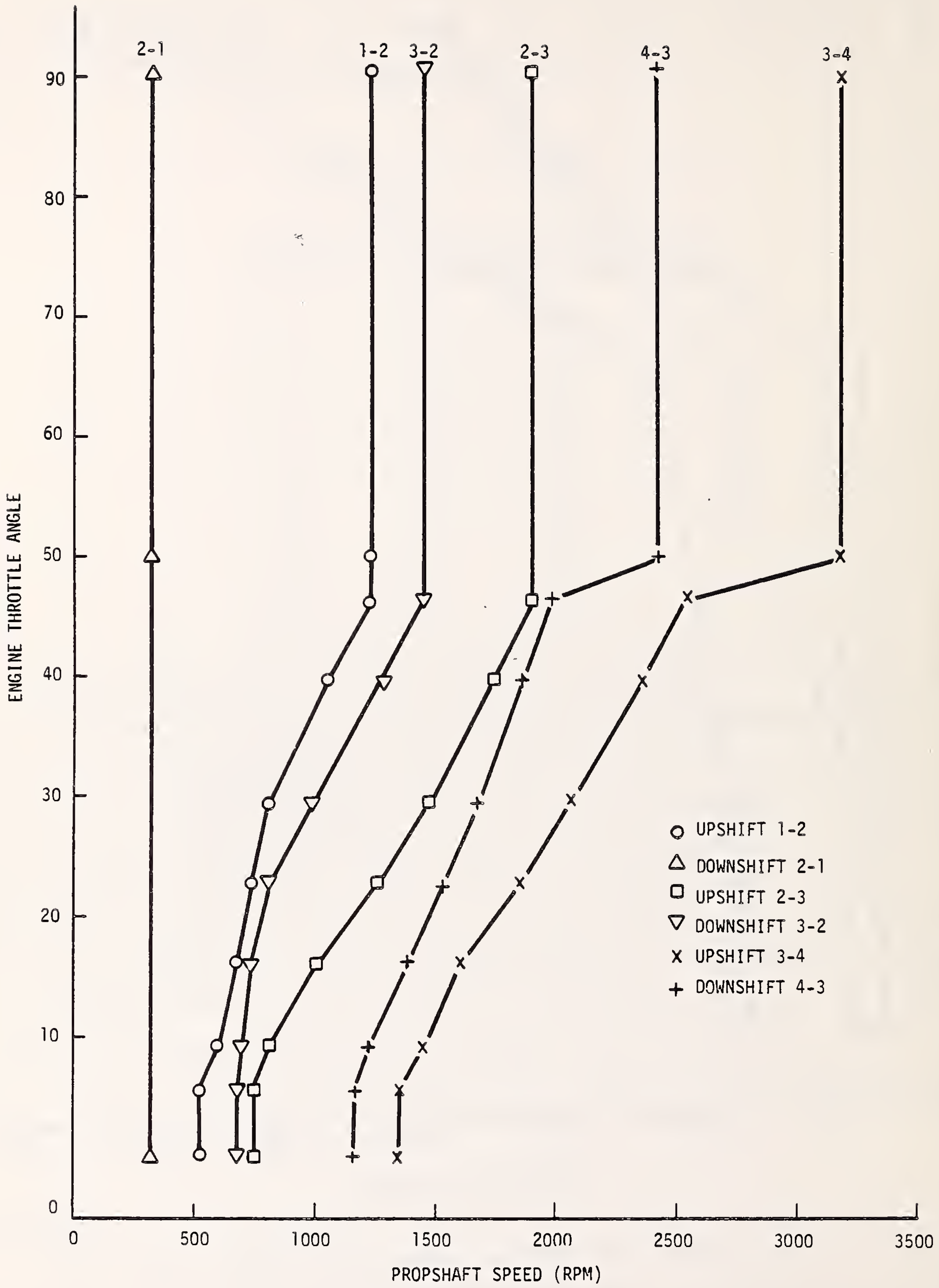

FIGURE 4-4. SAMPLE SHIFT LOGIC USING ENGINE THROTTLE ANGLE

presented in Figures 4-5 and 4-6. To facilitate an understanding of the converter, the user should understand the "K" factor and its effect on the torque converter curves. For example, when calculating road speed based on engine speed the SR (speed ratio) will vary depending upon engine load. Therefore, identical road speeds will not always produce identical engine speeds. This is an important factor to consider when programming shift logics

Because torque converter data is not always available, a method for determining torque converter characteristics has been established by Arthur D. Little based on fundamental equations.* Also, torque converters are sometimes referenced in terms of STR (stall torque ratio) which is the torque ratio at zero speed ratio. This is the maximum torque multiplication of the converter.

Torque converter data for both a coast and drive converter must be provided even in the case of a manual transmission, which is considered as a locked-up torque converter. The converter input to VEHSIM may be accomplished by two different methods depending on the format of the data received from the manufacturer.

ROUTE

The route specification is used to indicate distances and driving conditions. Maximum flexibility is provided for driving conditions by allowing them to be changed from one milepost to the next. The route specification and driving schedule must be checked for compatibility when grades and winds are utilized. For example, one would not specify a 75 MPH speed or a 5 percent grade with a 50 MPH headwind for a 4,500 pound vehicle. Grade changes must not exceed 1 percent incremental change for heavy duty trucks. Wind speed may be specified as either positive or negative for head winds or tail winds, respectively. Cross-winds

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*Hurter, Donald A., et. al., "Study and Test to Confirm Automobile Drivetrain Components to Improve Fuel Economy," Vol II., Report No. DOT-TSC-NHTSA-79-11 II, May 1979.

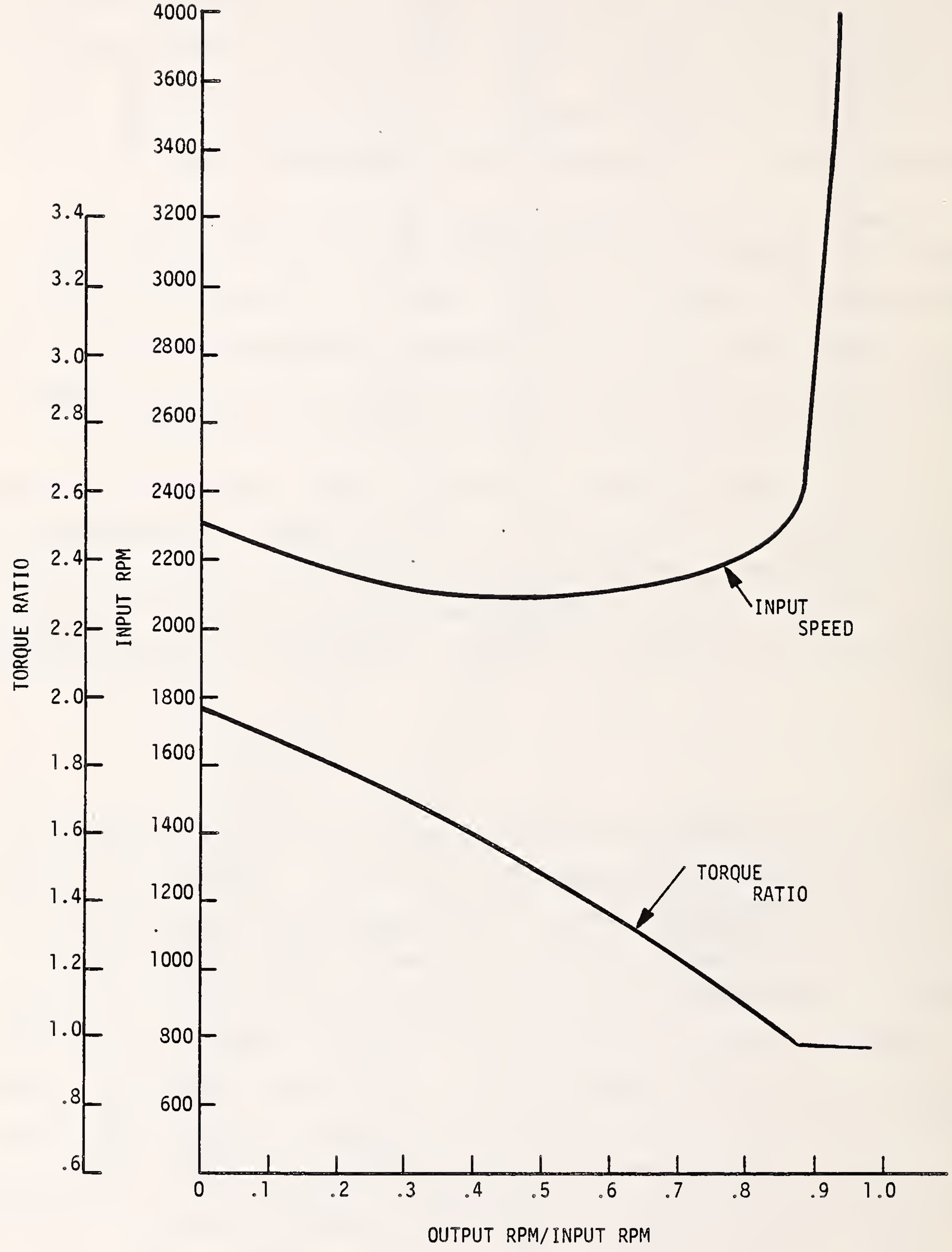

FIGURE 4-5. SAMPLE 9.5 INCH TORQUE CONVERTER CURVE

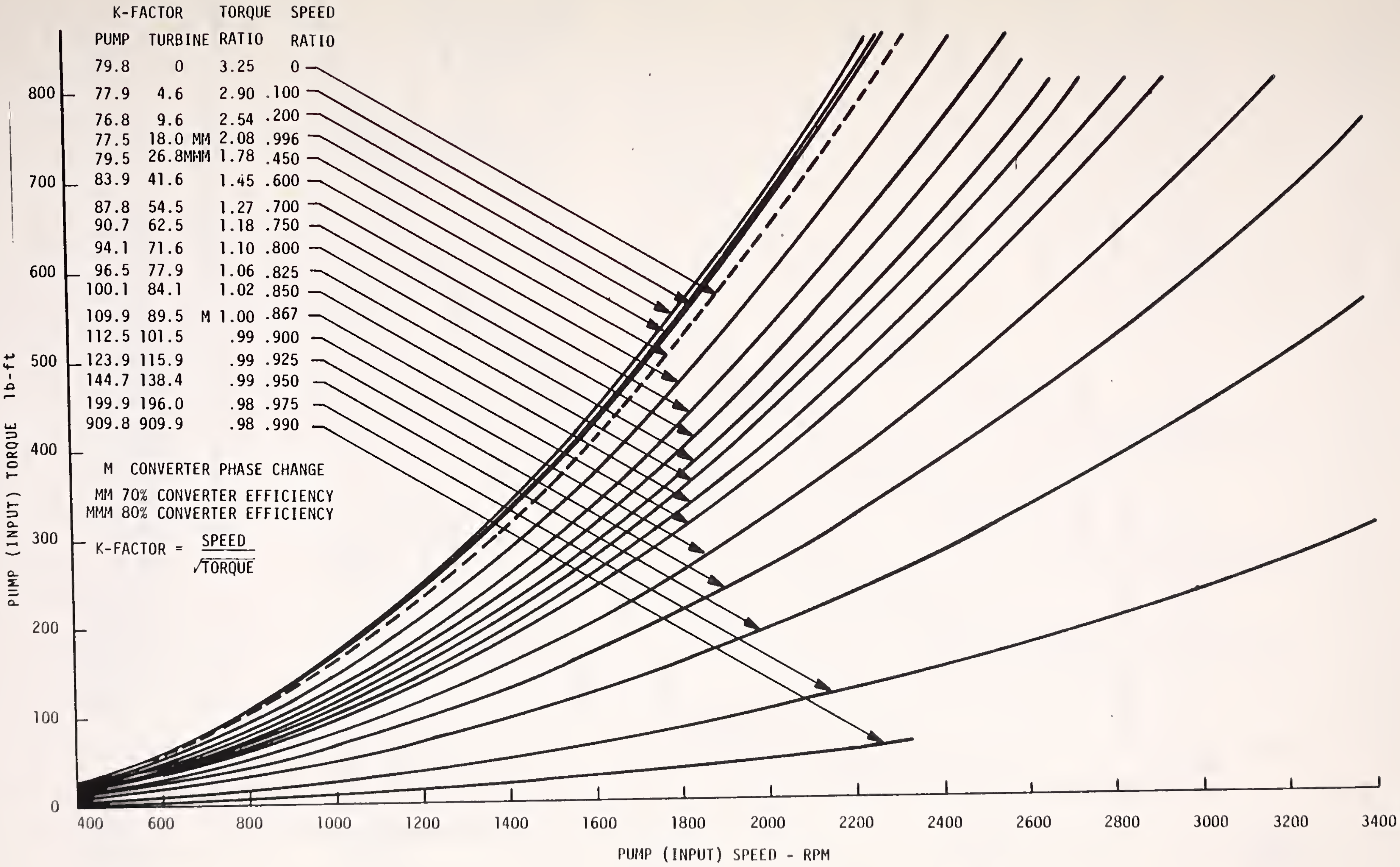

FIGURE 4-6. SAMPLE TORQUE CONVERTER CURVE ILLUSTRATING "K" FACTOR

may also be considered, but will not be discussed at this time due to wind data limitations and the unresolved question of applicability.

ACCESSORY

Accessories are simulated by means of torques for given accessory speeds. This information is obtained in a variety of formats. For example, the alternator is obtained in terms of different power (watts) settings as shown in Figure 4-7.* Once the required power settings are determined (e.g. headlights on or off) the appropriate power curve is used for the accessory loading. A simple systems calculation of the alternator input and output loads will help determine the validity of the data. Other accessory data such as that for air conditioners are harder to obtain because of the difficulty in controlling the duty cycle and ambient conditions such as temperature and humidity. If this data is available, care should be taken in determining the laboratory or on-road conditions during the test. The air conditioning data should not be used over the EPA highway or urban cycle since air conditioning is simulated by modifying the dynamometer horsepower by 10 percent up to a maximum of 1.5 hp.

Basically, VEHSIM "sees" the accessory load as a torque for a given engine speed (this speed must be in terms of engine speed which is obtained by using the accessory speed ratio). The most critical part of using accessories in the VEHSIM program is how the user interprets the data used to measure accessory loads. Once this is established and the user is confident of these results, the selection and input of the accessory is relatively simple.

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*Gagne, G. et. al., "Friction and Accessory Tests of a GM 1980, 151 CID Engine", Transportation Systems Center, Report No. DOT-TSC-NHTSA-80-19, May 1980.

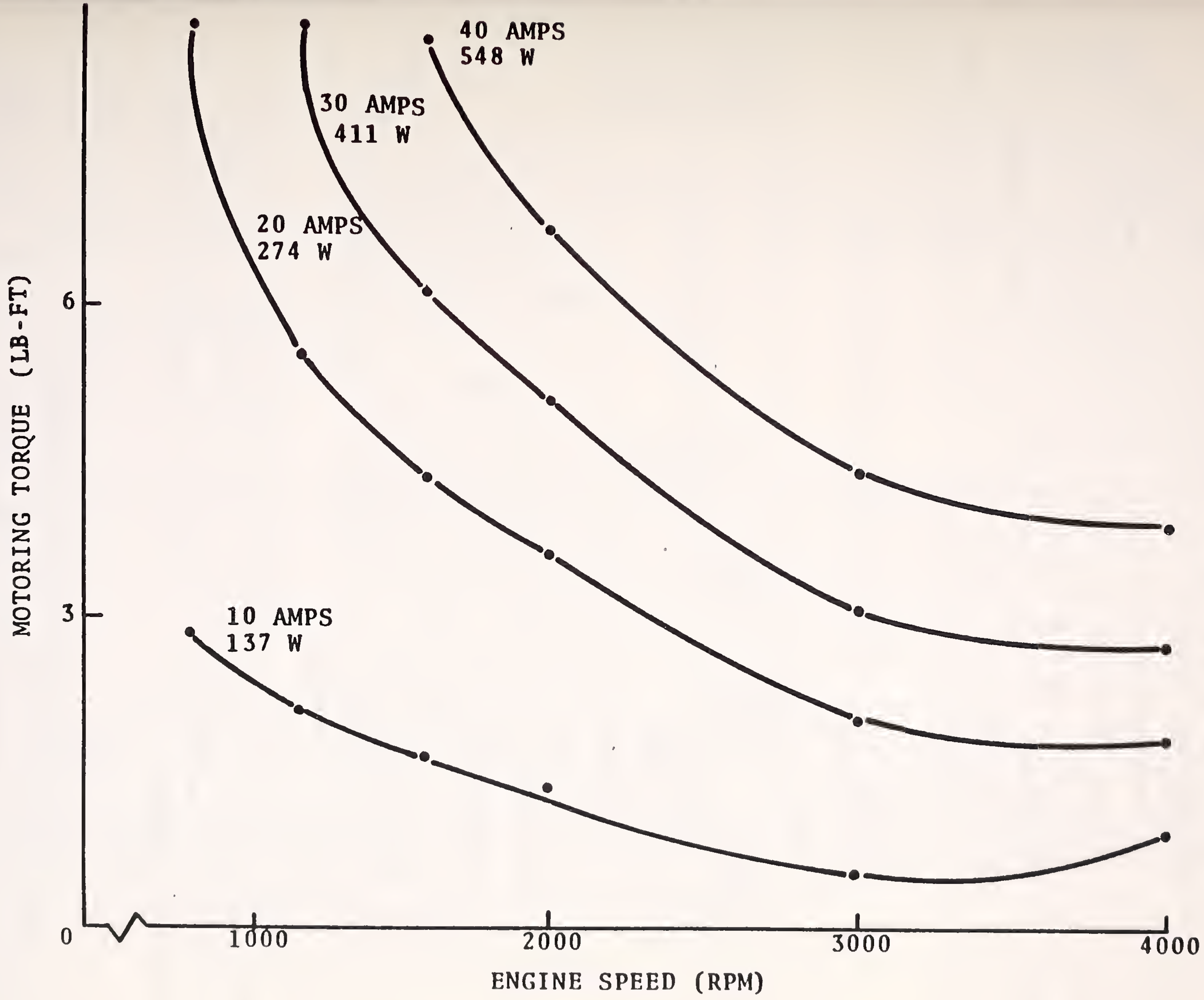


FIGURE 4-7. ALTERNATOR DRAG TORQUE VS. ENGINE SPEED

DRIVING SCHEDULE

Driving schedules can be divided into two categories, performance and fuel economy. Performance schedules include 0-60 mph, 0-1/4 mi, and the distance covered in 0-5 sec. With the exception of a passing schedule, all performance schedules, which are at WOT, can be consolidated into one top speed schedule. The gradeability can also be determined from this schedule. The fuel economy schedules are the EPA urban (FTP) and highway (HWFET), which are shown in Table 4-4 and Figure 4-8. Of course, any drive schedule can be created for performance or fuel economy purposes.

TABLE 4-4. DRIVING CYCLE CHARACTERISTICS

Driving cycle	Length, miles	Average speed, mph	Maximum speed, mph	Time, sec	No. of stops/cycle	Time at idle, %
FTP	7.5	20	57	1371	18	19.1
HWFET	10.25	48	60	765	2	1.0

The course of accelerations, cruises, decelerations, and stops are specified in the driving schedule. The courses may be initiated at other than zero conditions on the INITIAL COND card, and an application of this option would be a constant speed cruise such as for the 55 mph study. Accessory duty cycle is also specified in the initial conditions, although it applies throughout the entire driving schedule.

Data in each SEGMENT is grouped according to which data may be specified as only one, optional, or at least one. For the latter type of data, whichever condition is satisfied first will terminate the segment.

AXLE

The efficiency of the final drive varies slightly with speed and load and can be assumed constant for most simulation runs. Typi cal efficiencies are in the order of 95-98 percent. If the

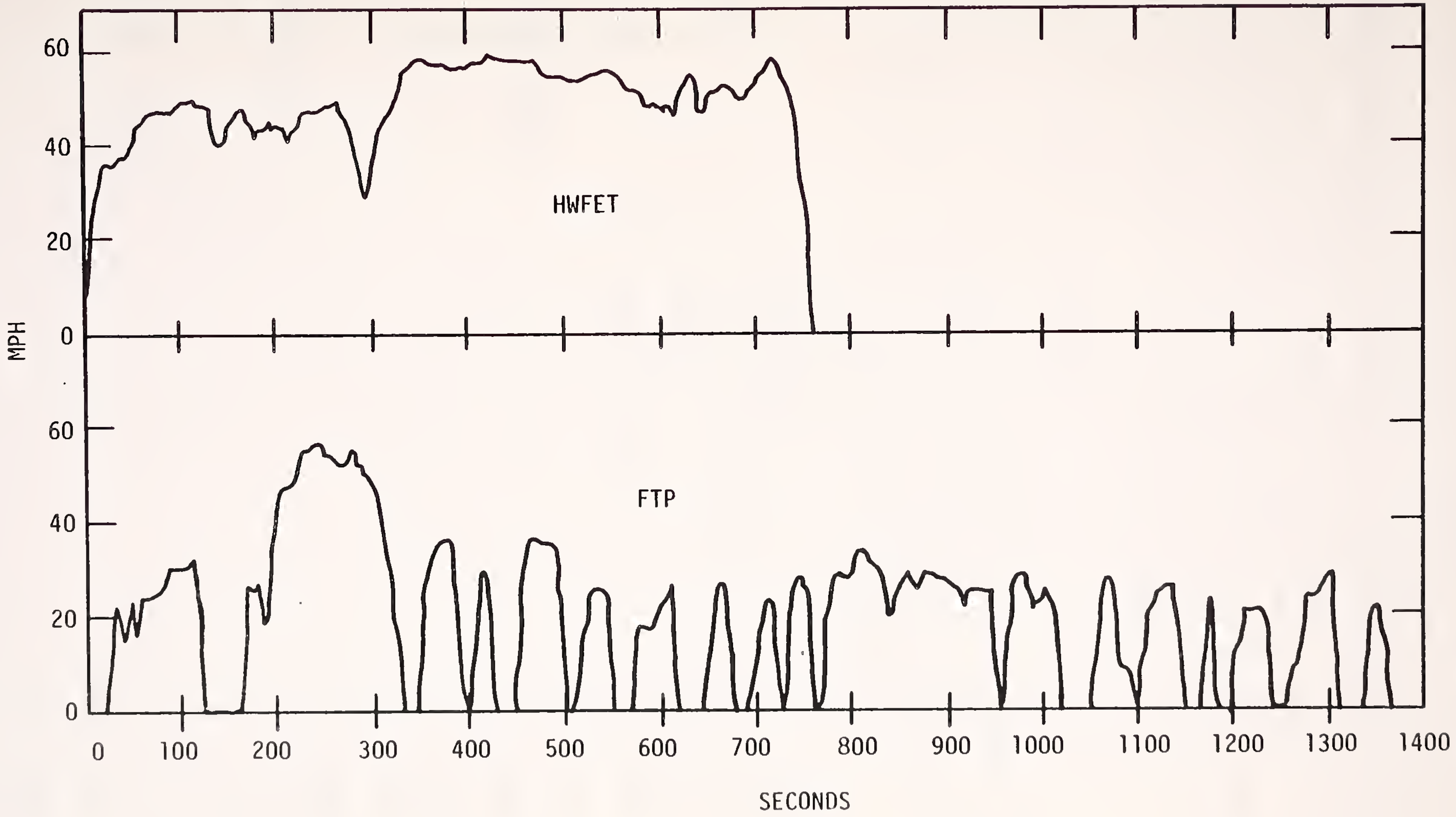


FIGURE 4-8. SPEED-VERSUS-TIME TRACES OF FTP AND HWFET DRIVING CYCLES

efficiency is constant and the spin losses are negligible, the axle should be included in the vehicle data base. However, the efficiency may vary considerably with light load and low speed. In this case, the user should estimate the efficiency based on a curve of axle efficiency as a function of load and speed.

5. INPUT DATA FORMAT

After reading Chapter IV the user is now ready to input the data according to the format required by VEHSIM. This chapter describes the precise format for data input on a line-by-line basis and indexed to numerical card (terminal) column numbers. Data sheets may be reproduced, filled out, and submitted directly for keypunching or remote terminal processing.

5.1 DATA FORMAT SHEET PROCEDURE

Input data for the program is punched on cards according to a specified format, and then read onto a disk or tape. The data format is provided for vehicle parts, specified procedures and utilities. The data format sheets are listed below:

PARTS DATA

(1) ACCESSORY
(2) AXLE
(3) CONVERTER
(4) CONVERTER (OPTIONAL FORM)
(5) ENGINE
(6) GEAR
(7) TIRE
(8) TRANSMISSION
(9) VEHICLE
(10) VEHICLE (OPTIONAL FORM)

PROCEDURES

(11) DRIVING SCHEDULE
(12) ROUTE
(13) SHIFT LOGIC

UTILITY

(14) DEBUG
(15) DROP
(16) DUMP
(17) LIMIT PRINT
(18) LOCKUP CONV.
(19) MODIFY
(20) PRINT UNITS
(21) REMAP
(22) SIMULATE
(23) TITLE
(24) UNLOCK CONV.
(25) USE
(26) ZERO
(27) SPLIT

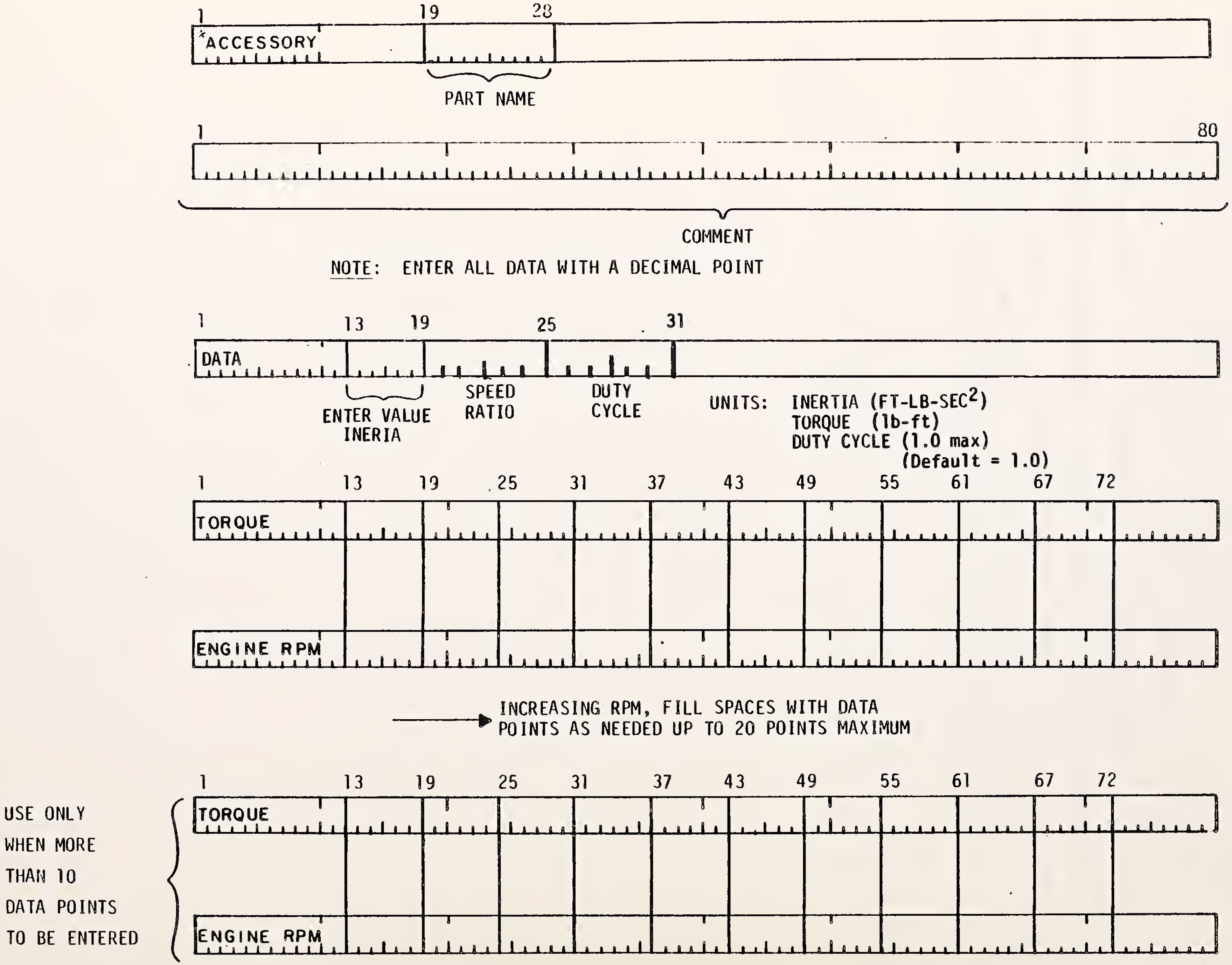
A brief description of the parts data and procedures is provided. The utility formats are self-explanatory and their uses are discussed in Section 2.

Each line on a data sheet indicates one line of code to be punched on a card or typed on a terminal. The columns of a data field within a line are indicated with the appropriate column number. Left-justifying the data, which is always entered in decimal form, facilitates keypunching. Alphabetic names or symbols already included on a data line must also be keypunched starting in the first column. Many of the data forms indicate repeated lines of data. For these cases there is no need to repeat the title line, comment line, and first data line. Part names may be made up of letters and numbers only (no symbols or special characters).

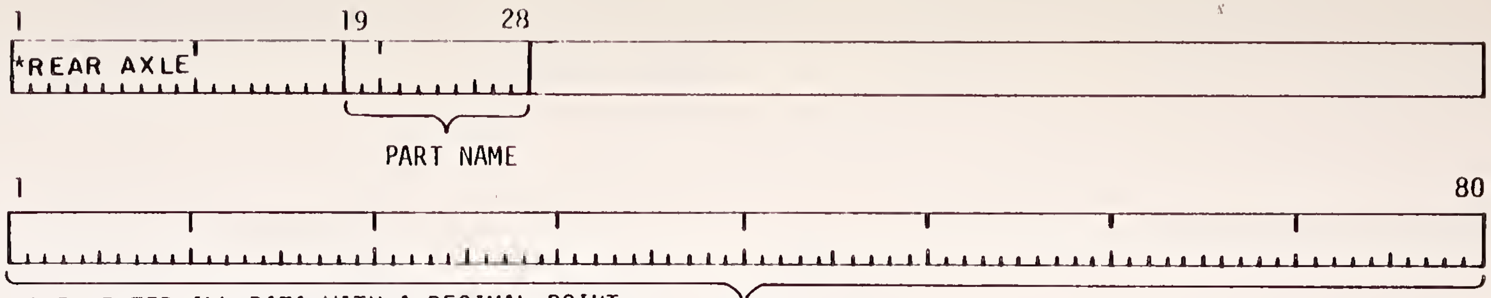
5.2 DATA SHEETS

The data sheets for parts data, procedures, and utility commands are described in this section. The format of the data sheets is similar to standard keypunch coding forms. Each part is described on a separate sheet with mandatory key words or phrases already indicated on the sheet. Each new part begins with an asterisk in column one of the first line, followed by the type of part, procedure or utility command. The remaining spaces are to be filled in with data where indicated by explanations on each form.

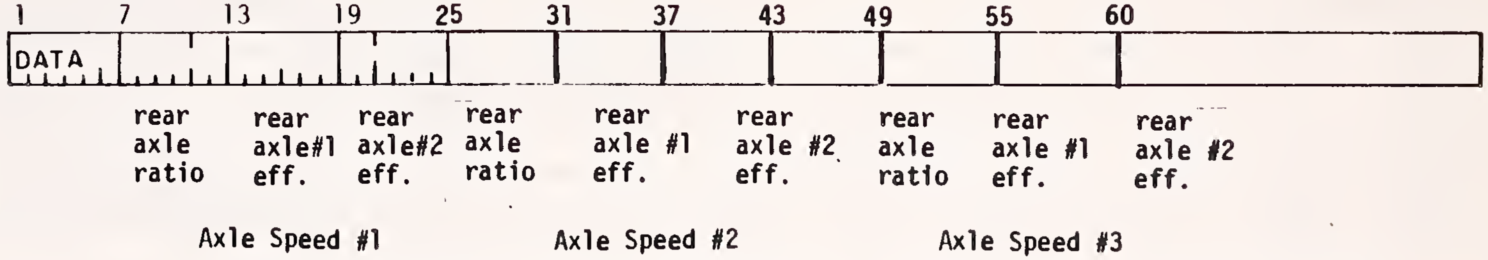
DATA SHEET 1. ACCESSORY



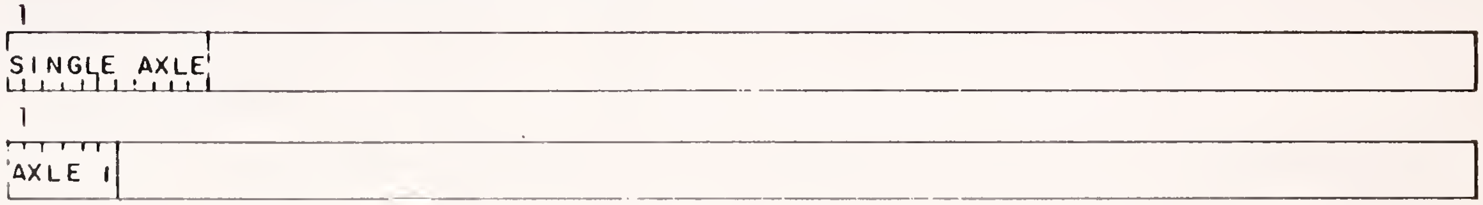
DATA SHEET 2. AXLE (Sheet 1 of 2)



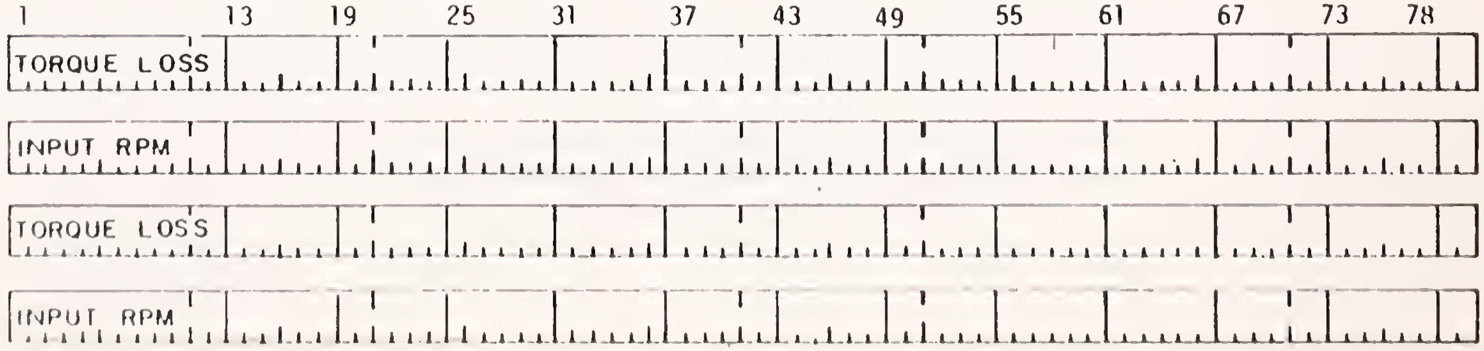
NOTE: ENTER ALL DATA WITH A DECIMAL POINT
AXLE #1 FORWARD-REAR AXLE (or single)
AXLE #2 REARWARD-REAR AXLE



NOTE: USE SINGLE AXLE IF ONLY ONE AXLE. DO NOT USE AXLE 1 OR AXLE 2 TITLES.
USE AXLE 1 AND AXLE 2 IF DOUBLE AXLE.



SPIN LOSSES:



DATA SHEET 2. AXLE (Sheet 2 of 2)

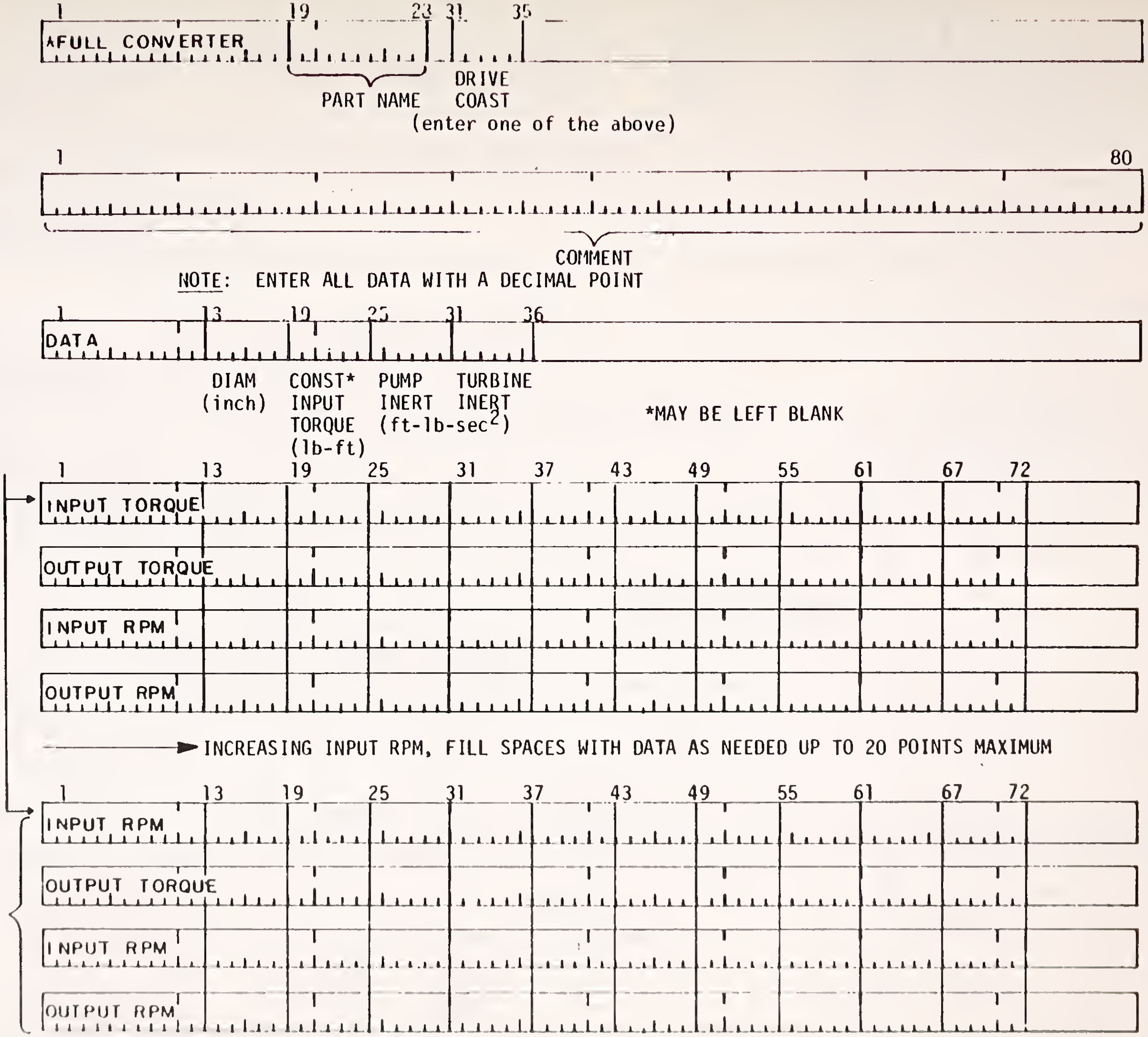
NOTE: ENTER ALL DATA WITH A DECIMAL POINT
TORQUE LOSS IN UNITS OF: LB-FT

1	13	19	24
AXLE 2			
	Axle #	Axle Speed #	

SPIN LOSSES

1	7	13	19	25	31	37	43	49	55	61	67	73	78
TORQUE LOSS													
INPUT RPM													
TORQUE LOSS													
INPUT RPM													

DATA SHEET 3. CONVERTER



NOTE: ENTER ALL DATA WITH A DECIMAL POINT

*MAY BE LEFT BLANK

LEAVE BLANK IF CONSTANT INPUT TORQUE IS SPECIFIED

→ INCREASING INPUT RPM, FILL SPACES WITH DATA AS NEEDED UP TO 20 POINTS MAXIMUM

USE ONLY WHEN MORE THAN 10 DATA POINTS TO BE ENTERED

DATA SHEET 4. CONVERTER (OPTIONAL FORM)

1	19	28	31	35
*S.R. CONVERTER				
	PART NAME		DRIVE COAST	

(enter one of the above)

1	80
COMMENT	

NOTE: ENTER ALL DATA WITH A DECIMAL POINT

1	13	19	25	31	36
DATA					
	DIAM (inch)	CONST* INPUT TORQUE (LB-FT)	PUMP INERT (ft-lb-sec^2)	TURBINE INERT	

*CONST INPUT TORQUE MUST BE SPECIFIED

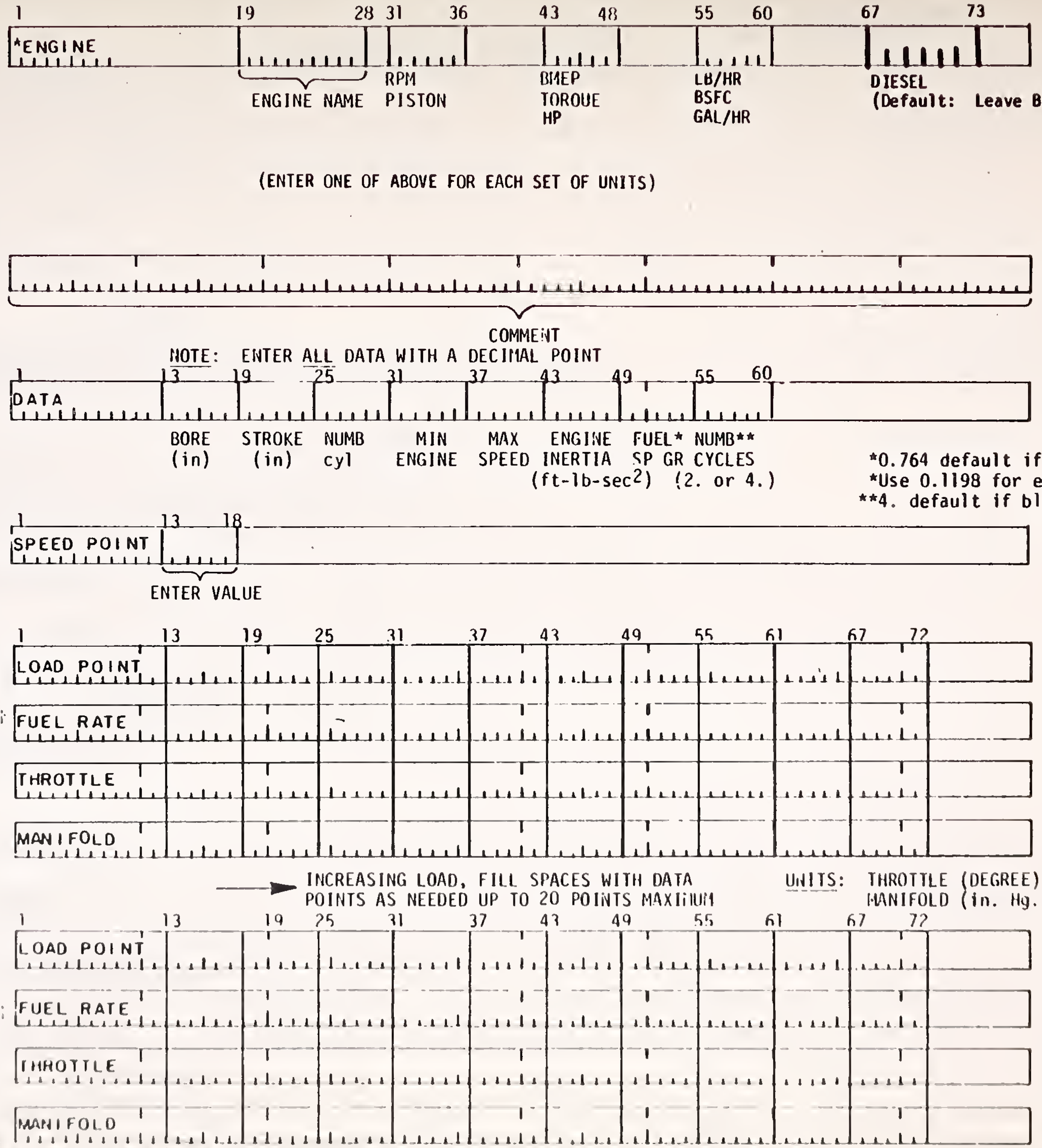
1	13	19	25	31	37	43	49	55	61	67	72
SPEED RATIO											
TORQUE RATIO											
INPUT RPM											

→ INCREASING RPM, FILL SPACES WITH DATA AS NEEDED UP TO 20 POINTS MAXIMUM

USE ONLY WHEN MORE THAN 10 DATA POINTS TO BE ENTERED

1	13	19	25	31	37	43	49	55	61	67	72
SPEED RATIO											
TORQUE RATIO											
INPUT RPM											

DATA SHEET 5. ENGINE (Sheet 1 of 2)



*0.764 default if blank
*Use 0.1198 for emissions
**4. default if blank

REPEAT SPEED POINT SETS AS NEEDED UP TO 20 SPEED PTS.

USE ONLY WHEN MORE THAN 10 DATA POINTS TO BE ENTERED

Emission rate (gm/hr) may be entered in FUEL RATE data field. See also *notes.

DATA SHEET 5. ENGINE (Sheet 2 of 2)

1	13	18
SPEED POINT		
	ENTER VALUE	

1	13	19	25	31	37	43	49	55	61	67	72
LOAD POINT											
FUEL RATE											
THROTTLE											
MANIFOLD											

1	13	18
SPEED POINT		
	ENTER VALUE	

1	13	19	25	31	37	43	49	55	61	67	72
LOAD POINT											
FUEL RATE											
THROTTLE											
MANIFOLD											

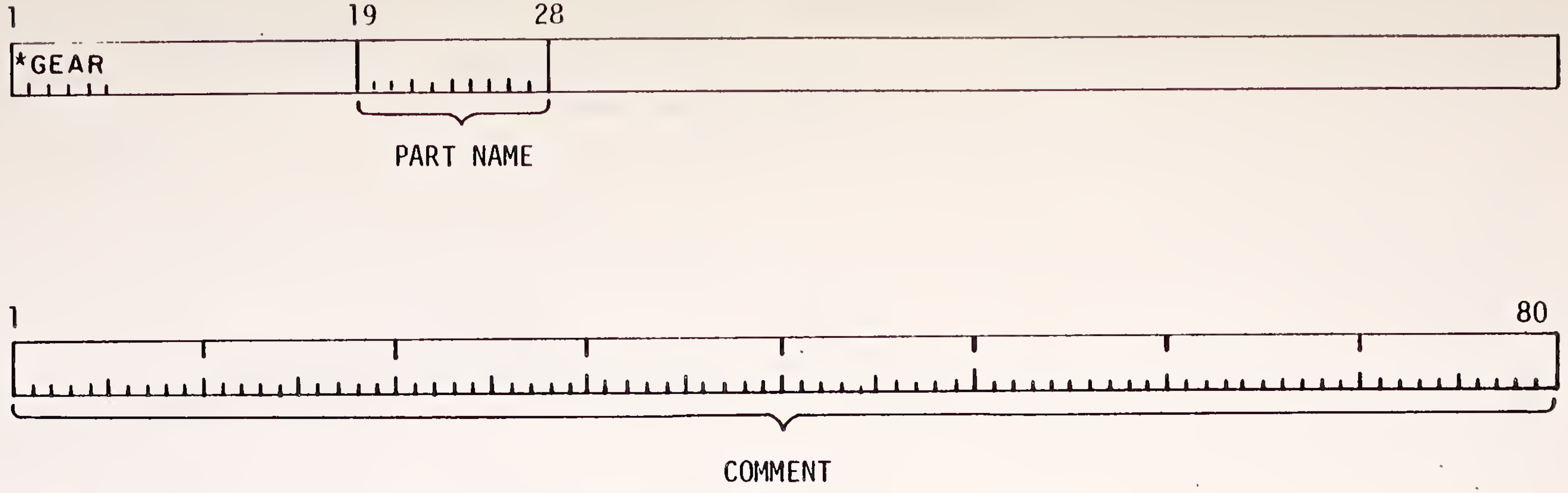
1	13	18
SPEED POINT		
	ENTER VALUE	

1	13	19	25	31	37	43	49	55	61	67	72
LOAD POINT											
FUEL RATE											
THROTTLE											
MANIFOLD											

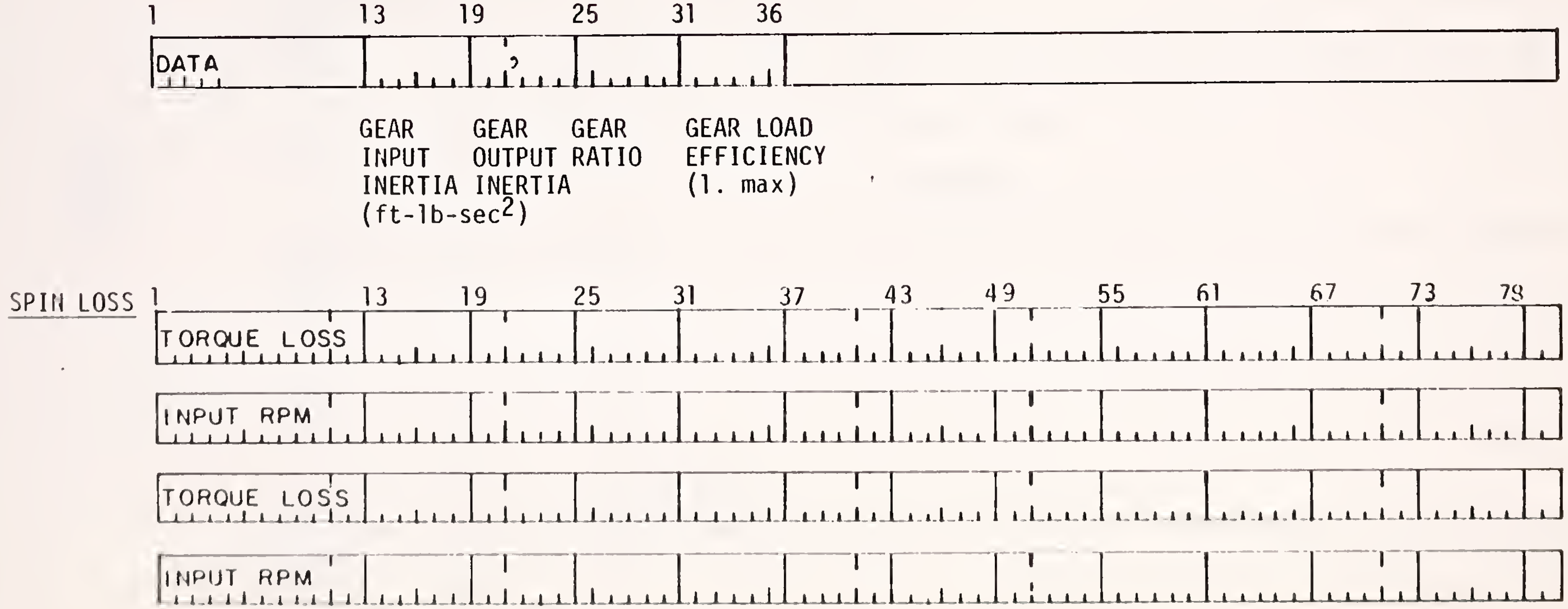
Increasing load, fill spaces with data points as needed up to 20 points maximum

Units: throttle (deg)
manifold (in Hg)

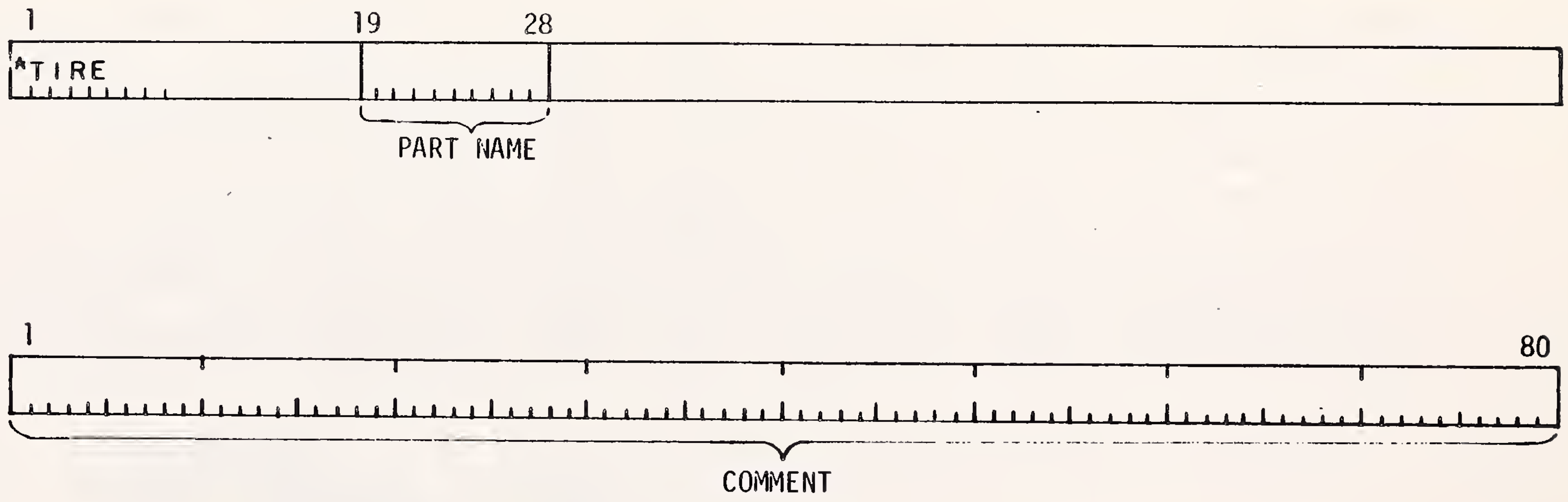
DATA SHEET 6. GEAR



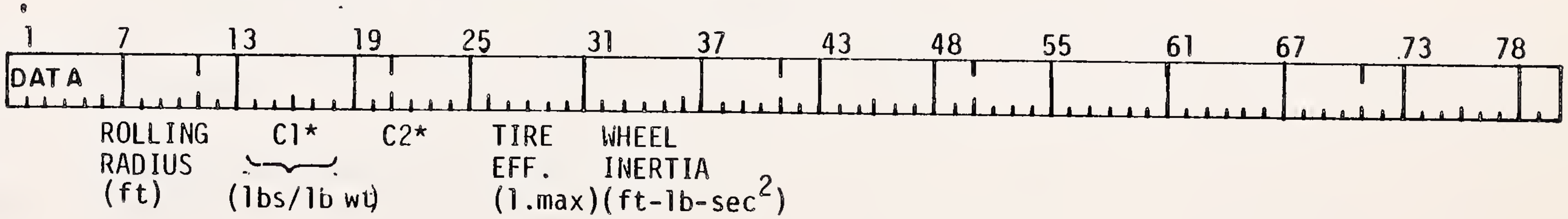
NOTE: ENTER ALL DATA WITH A DECIMAL POINT
TORQUE LOSS IN UNITS OF: LB-FT



DATA SHEET 7. TIRE

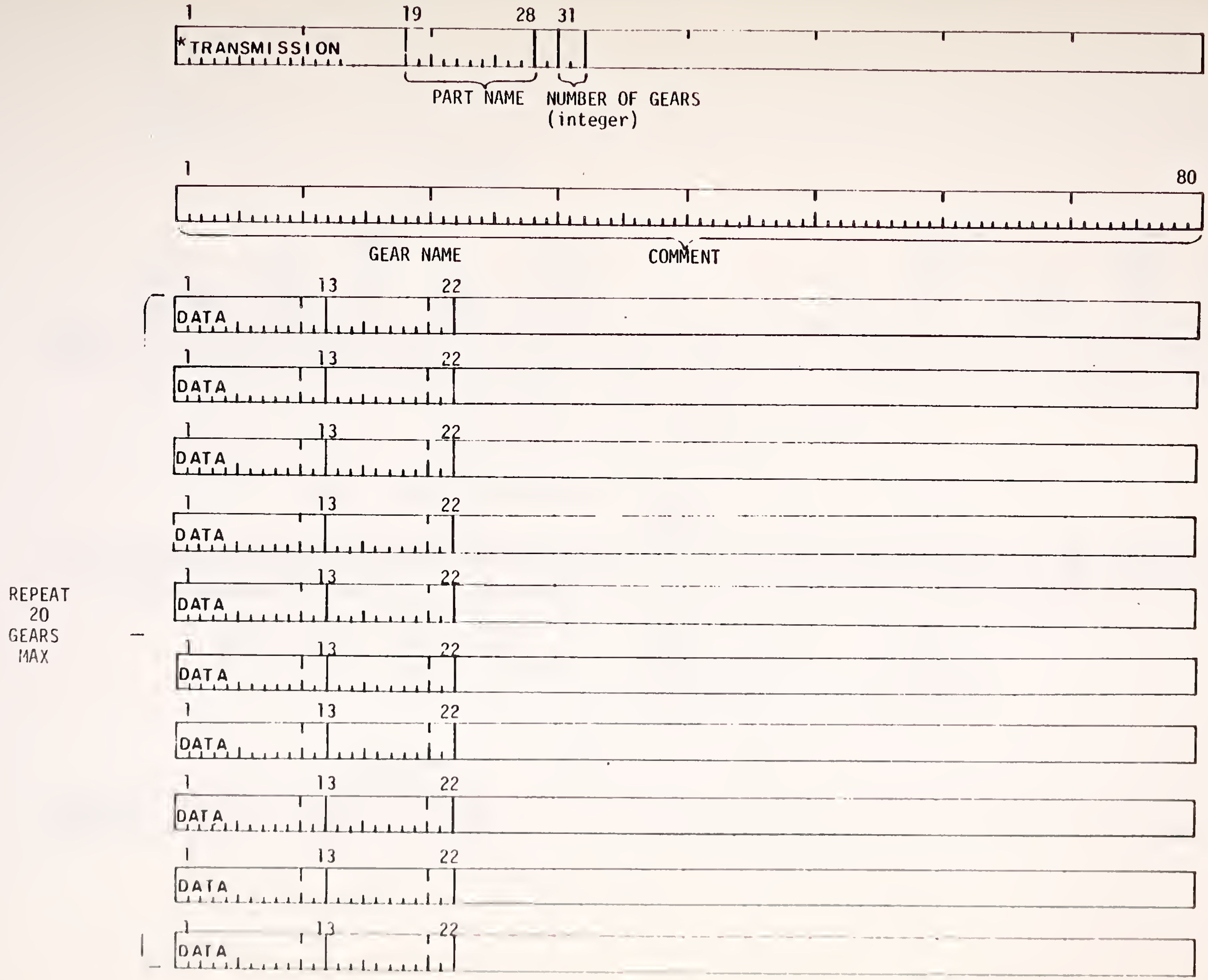


NOTE: ENTER ALL DATA WITH A DECIMAL POINT

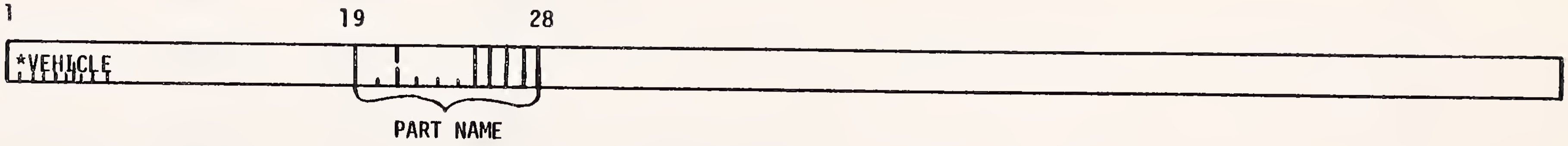


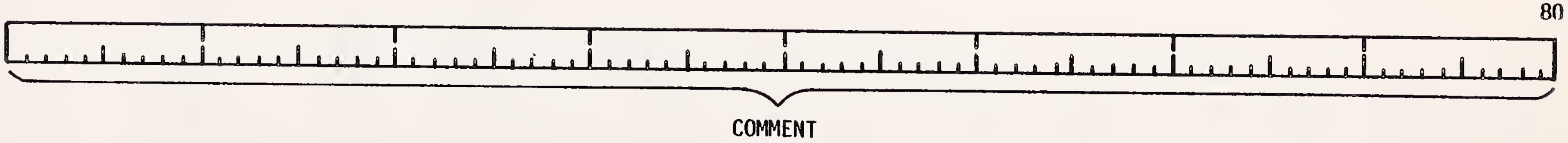
*Rolling resistance coefficients. Make C2 zero for linear approximation.

DATA SHEET 8. TRANSMISSION

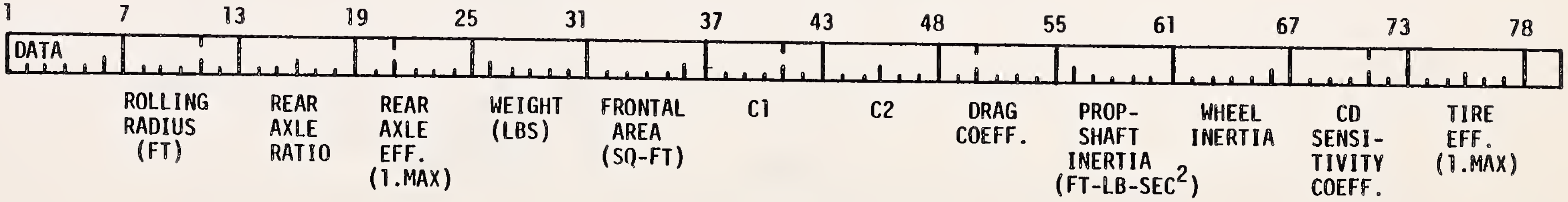


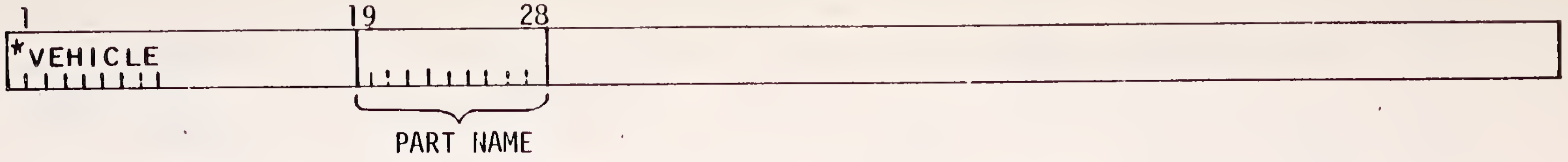
DATA SHEET 9. VEHICLE

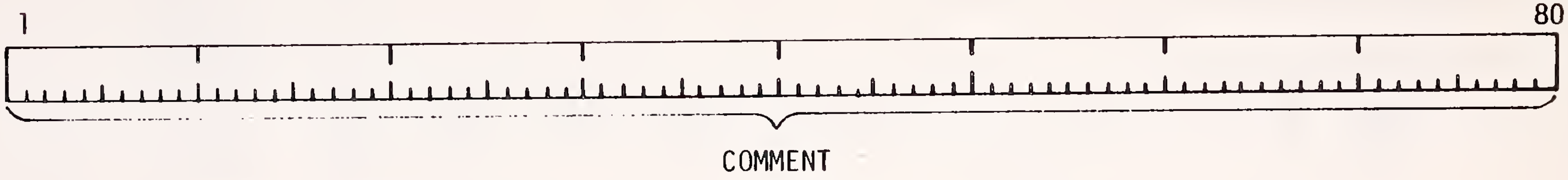




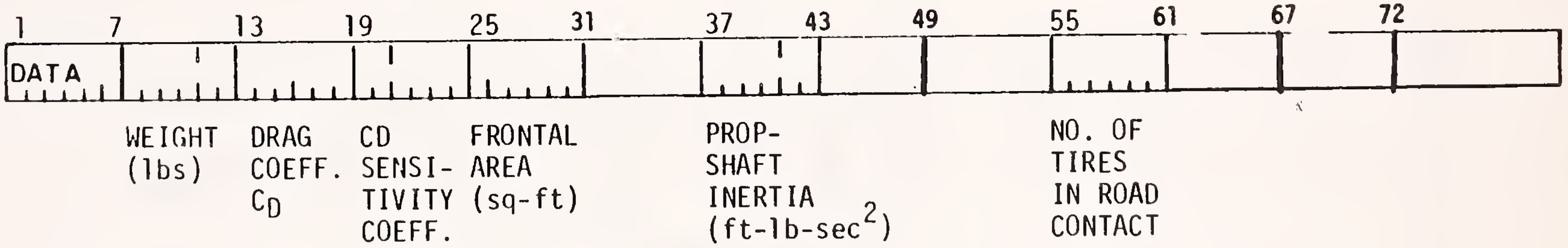
NOTE: ENTER ALL DATA WITH A DECIMAL POINT



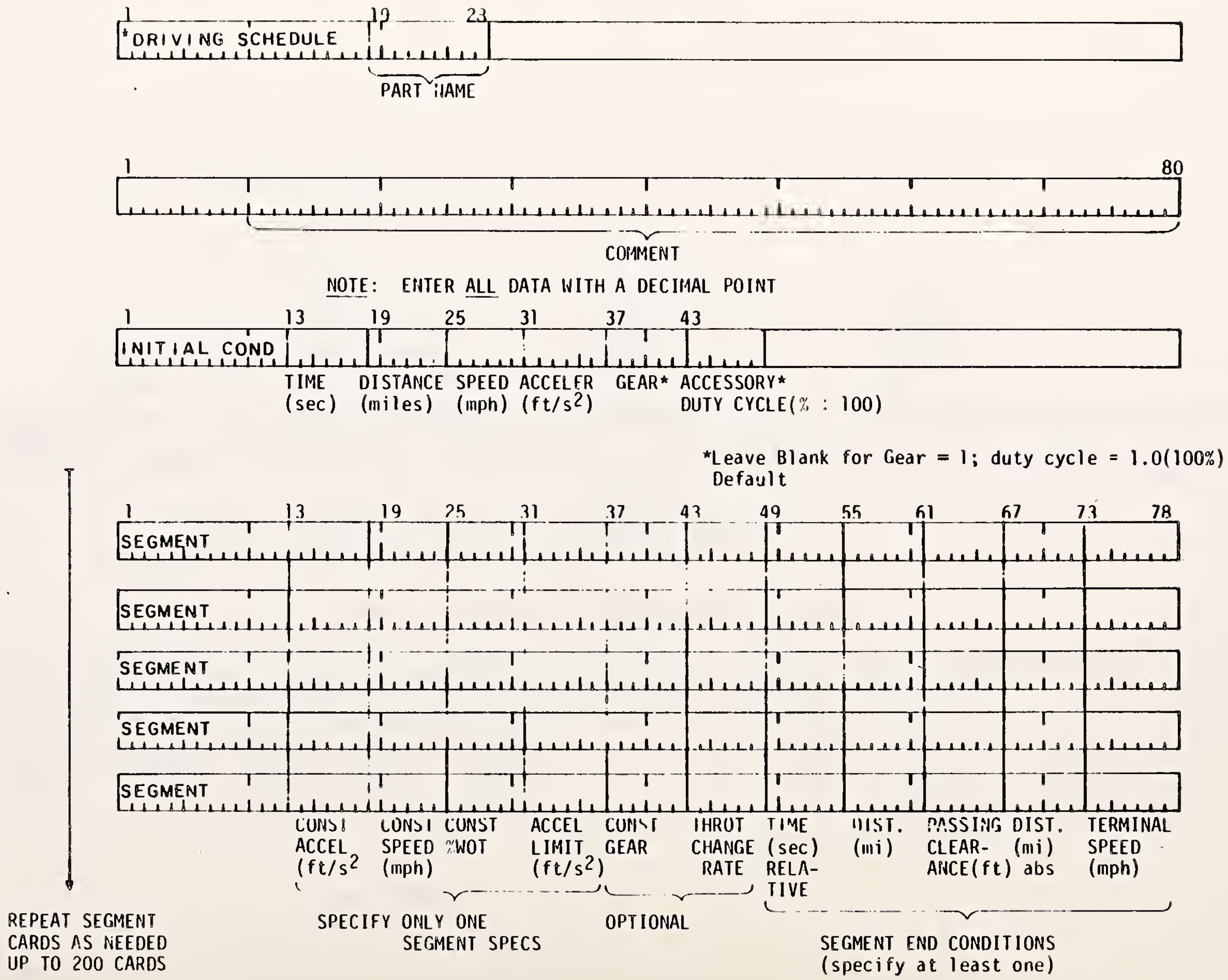




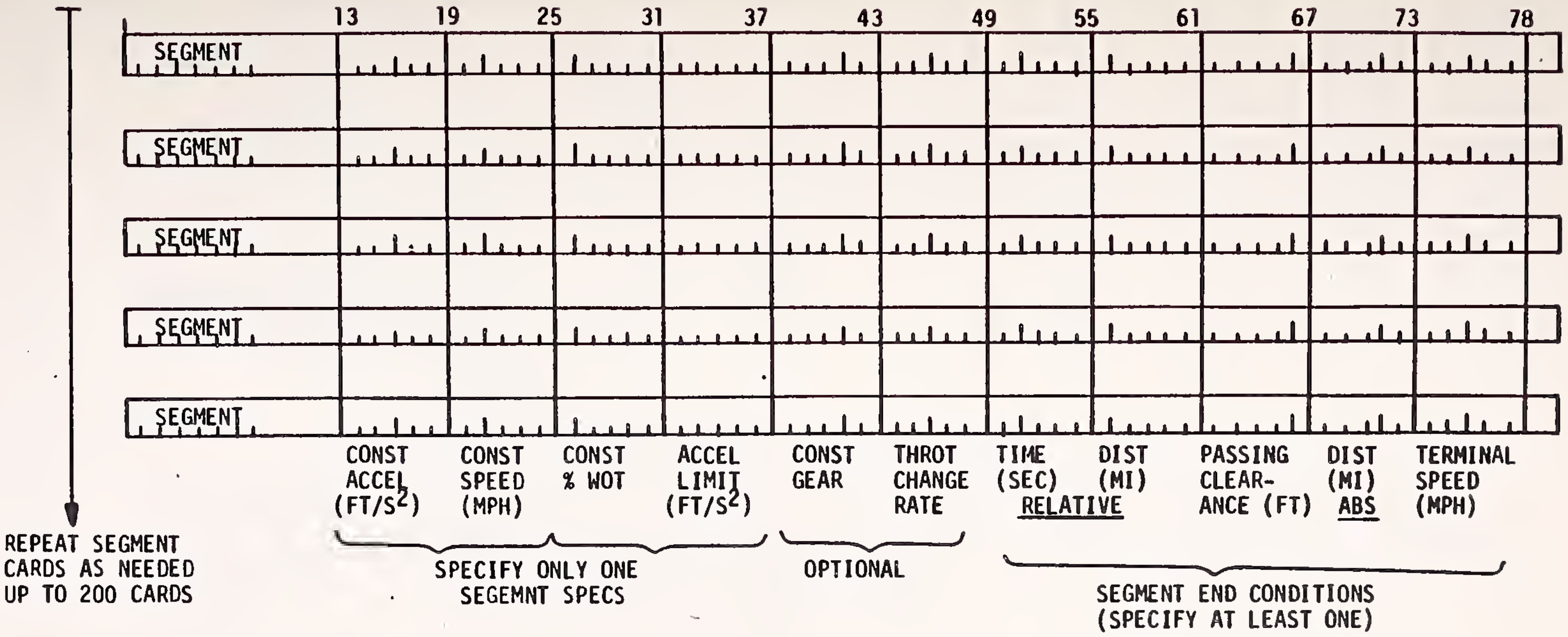
NOTE: ENTER ALL DATA WITH A DECIMAL POINT

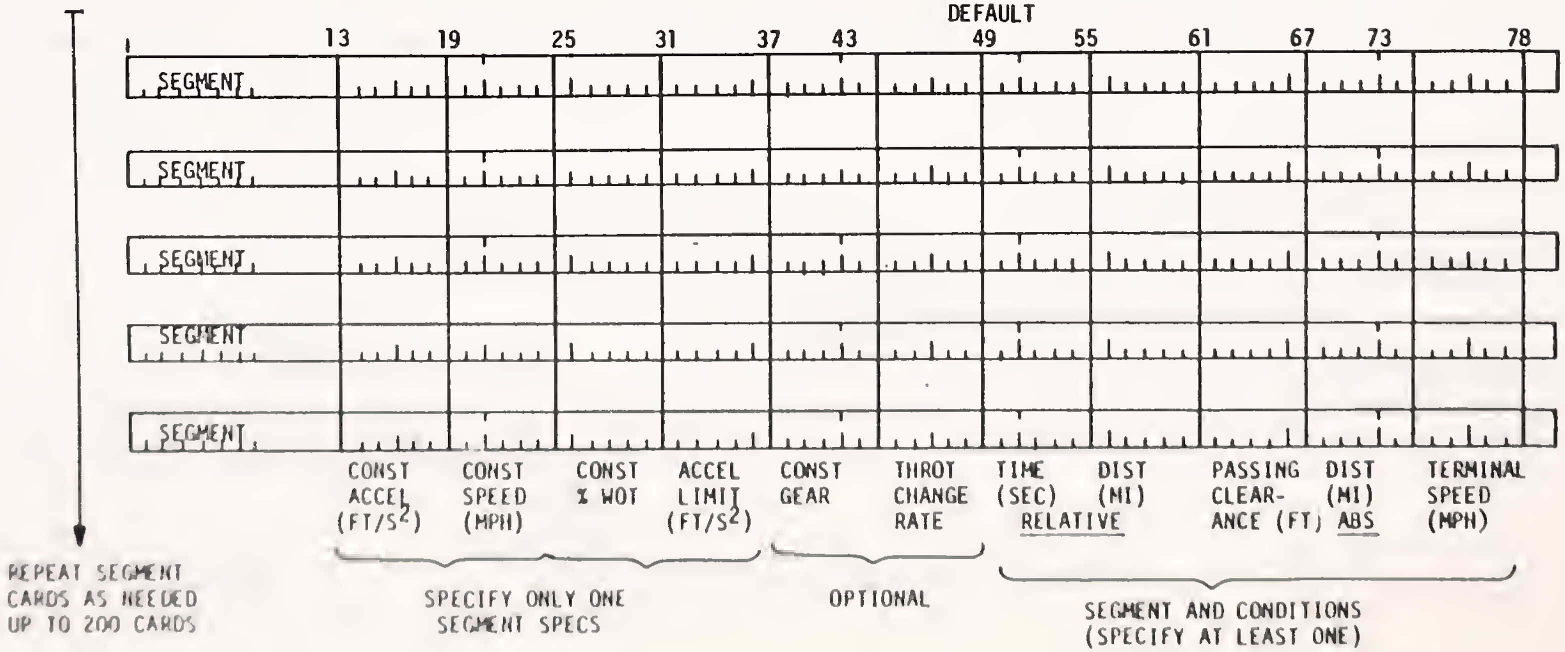


DATA SHEET 11. DRIVING SCHEDULE (Sheet 1 of 2)

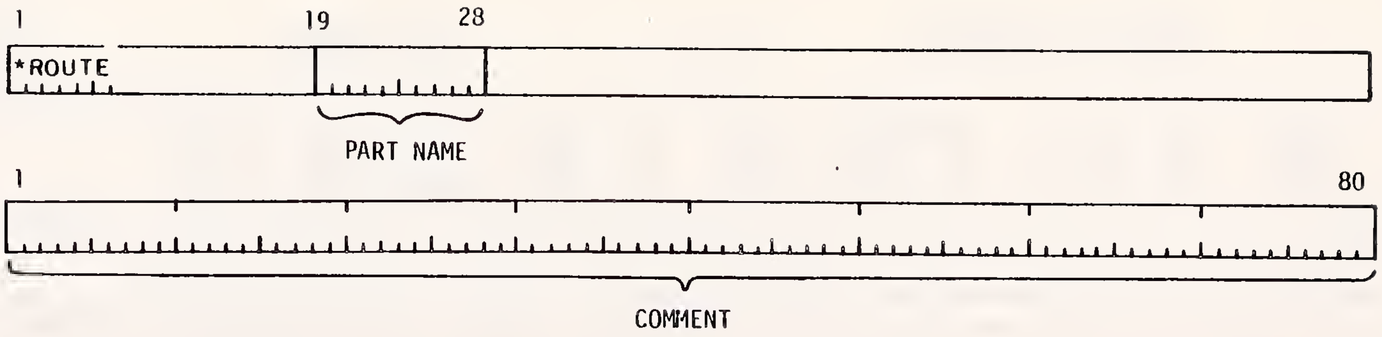


DATA SHEET 11. DRIVING SCHEDULE (Sheet 2 of 2)



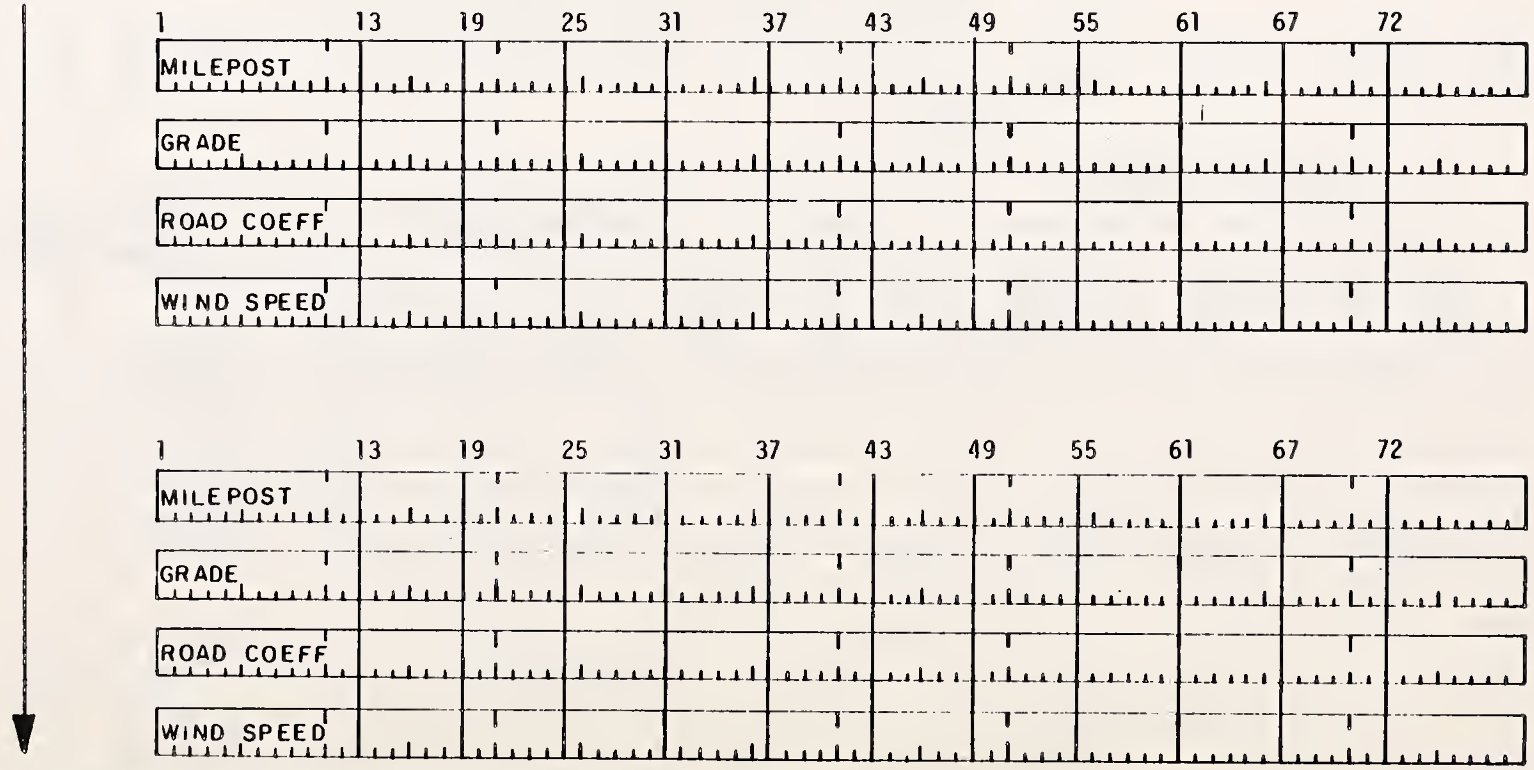


DATA SHEET 12. ROUTE



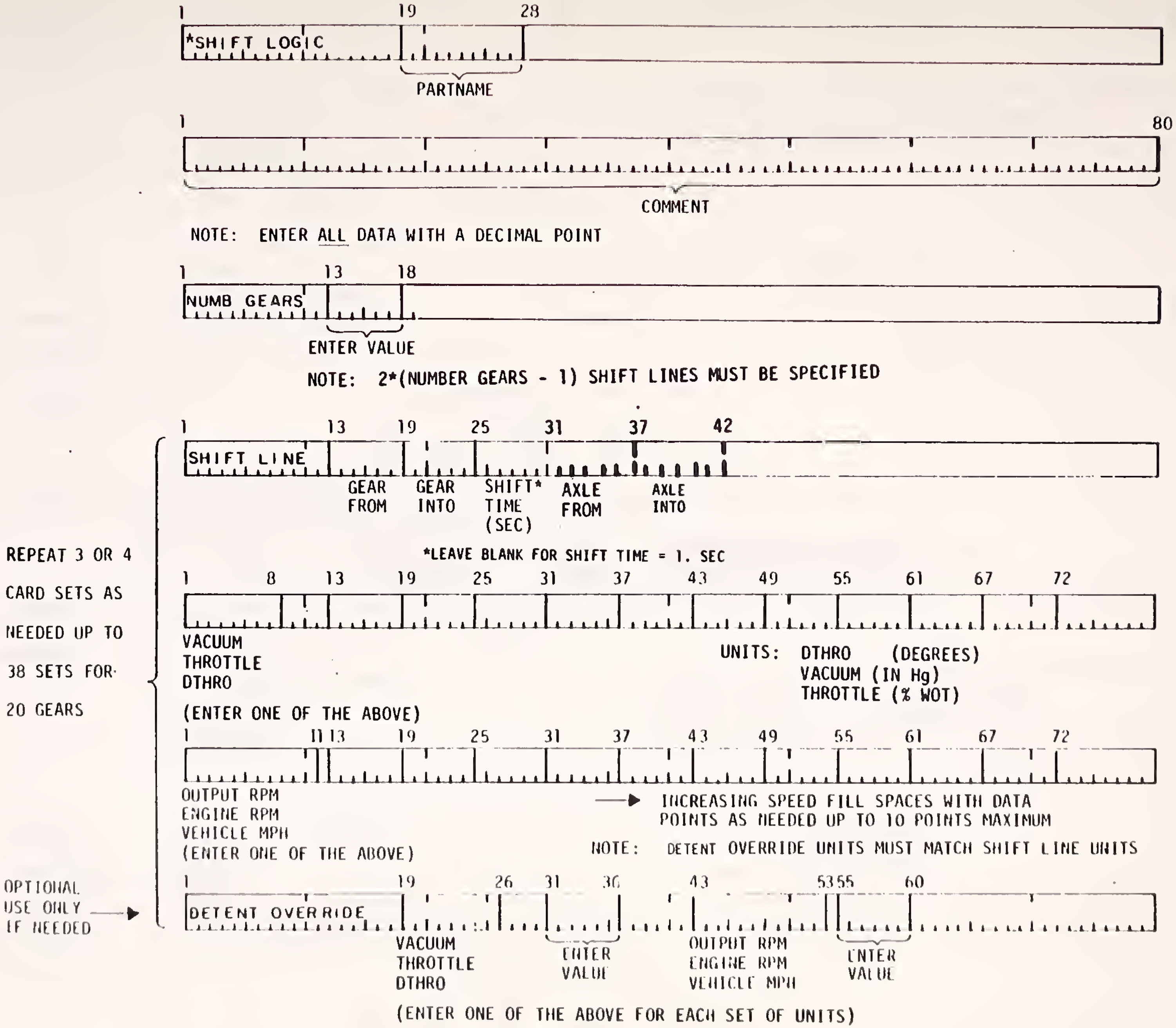
NOTE: ENTER ALL DATA WITH A DECIMAL POINT
SPECIFY GRADE AND ROAD COEFF FOR
UP TO THE DATA POINT MILEPOST

UNITS: MILEPOST (absolute miles)
GRADE (%)
ROAD COEFF (1.0 max)
WIND SPEED (mph)



REPEAT 4-CARD SETS AS NEEDED UP TO 10 SETS (100 points maximum)

DATA SHEET 13. SHIFT LOGIC (Sheet 1 of 2)



NOTE: ENTER ALL DATA WITH A DECIMAL POINT

NOTE: 2*(NUMBER GEARS - 1) SHIFT LINES MUST BE SPECIFIED

*LEAVE BLANK FOR SHIFT TIME = 1. SEC

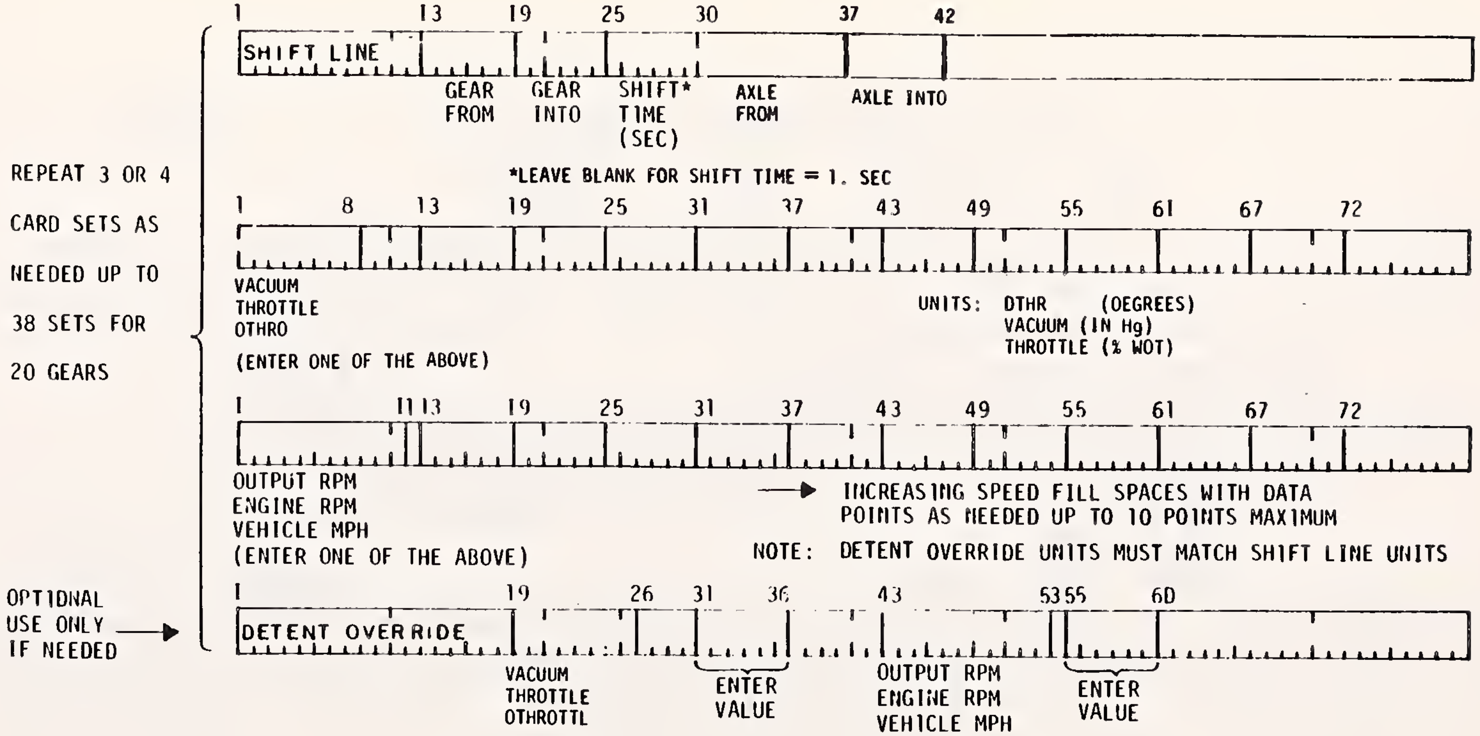
UNITS:
DTHRO (DEGREES)
VACUUM (IN Hg)
THROTTLE (% WOT)

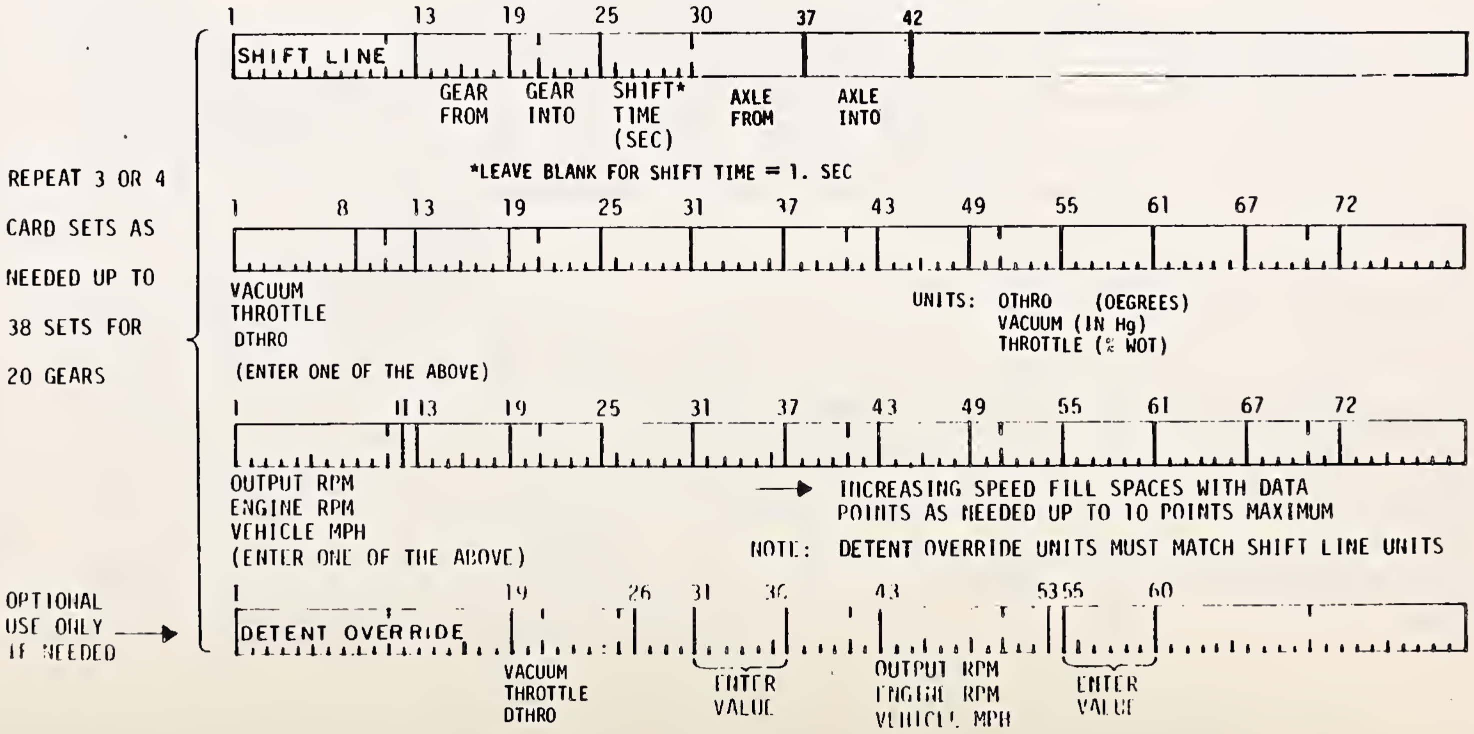
→ INCREASING SPEED FILL SPACES WITH DATA POINTS AS NEEDED UP TO 10 POINTS MAXIMUM

NOTE: DETENT OVERRIDE UNITS MUST MATCH SHIFT LINE UNITS

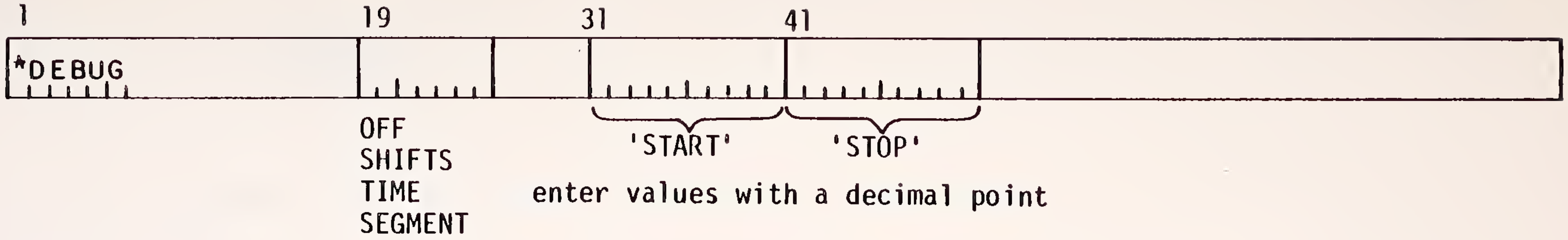
(ENTER ONE OF THE ABOVE FOR EACH SET OF UNITS)

DATA SHEET 13. SHIFT LOGIC (Sheet 2 of 2)



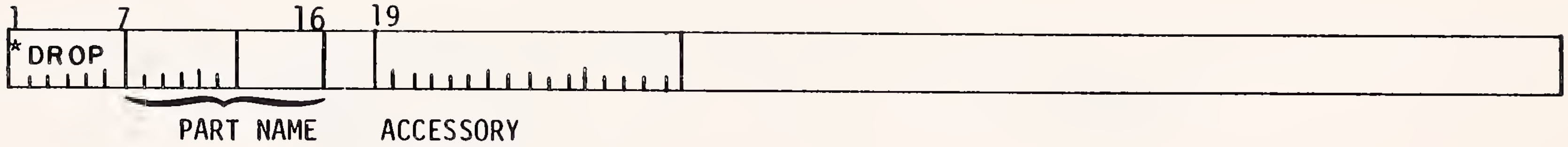


DATA SHEET 14. DEBUG



NOTES: FOR SHIFTS AND SEGMENT, ENTER SEGMENT NUMBERS
FOR TIME, ENTER VALUES IN SECONDS
IF NO 'START' SPECIFIED, DEBUG PRINTOUT STARTS AT BEGINNING OF RUN
IF NO 'STOP' SPECIFIED, DEBUG PRINTOUT CONTINUES TO END OF RUN

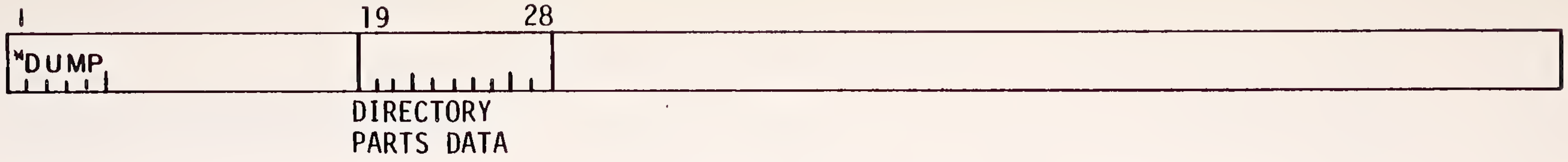
DATA SHEET 15. DROP



ACCESSORY
CONVERTER
DRIVING SCHEDULE
ENGINE
GEAR
ROUTE
SHIFT LOGIC
VEHICLE

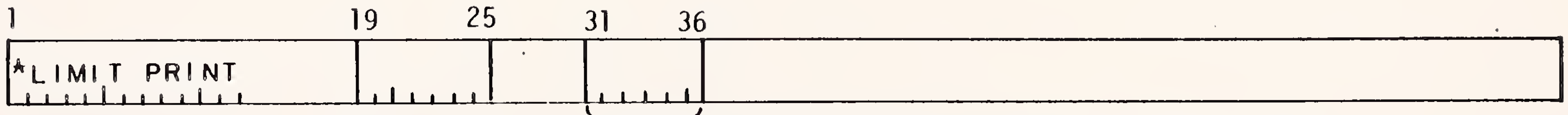
(enter one of the above)

DATA SHEET 16. DUMP



(enter one of the above)

DATA SHEET 17. LIMIT PRINT



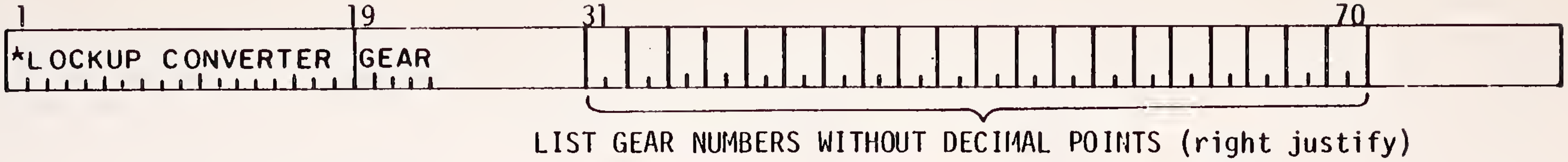
MILE
SEC
SEGMENT
OFF - FOR DETAILED PRINTOUT (including parts used data)
SUMMARY

ENTER VALUE FOR MILE, SEC WITH A DECIMAL POINT
(.1 mile, 10. sec defaults if no value entered)

(enter one of the above)

NOTE: IF NO LIMIT PRINT COMMANDED,
PRINTOUT IS SUMMARY ONLY

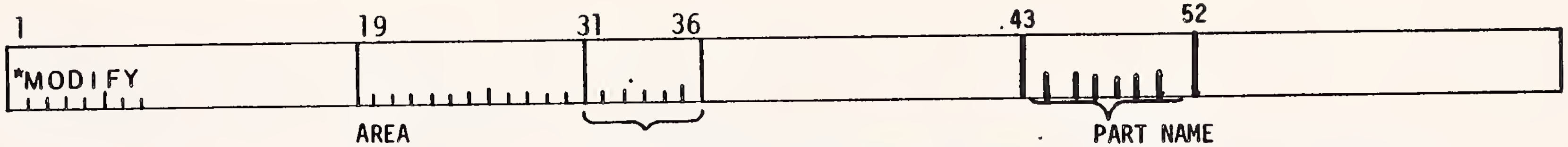
DATA SHEET 18. LOCKUP CONVERTER GEAR



LIST GEAR NUMBERS WITHOUT DECIMAL POINTS (right justify)

NOTE: GEAR NUMBERS RANGE FROM 1 to 20

DATA SHEET 19. MODIFY



enter value with decimal point

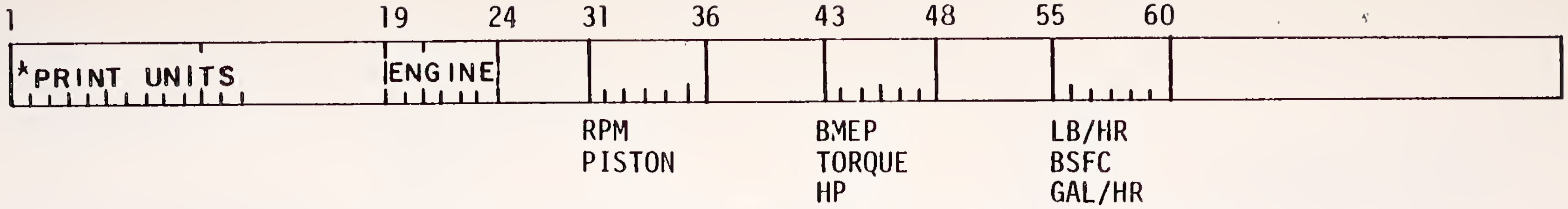
PART NAME
OPTIMAL
(MUST USE WITH DUTY CYCLE)

AREA
C1
C2
C4
CD
CYLINDERS
DIESEL
DISPLACEMENT
DUTY CYCLE
FUEL DENSITY
DYNAMOMETER
REAR AXLE R
STROKE
TIRE EFF
WEIGHT
WHEEL
WIND
IDLE
STEP
UPSHIFT
DOWNSHIFT
TRR
PHI
TOPSPEED
LOCKUP 2 NUMBERS | RRM GEAR NUMBER
| >1=ON
| 0=OFF

(enter one of the above)

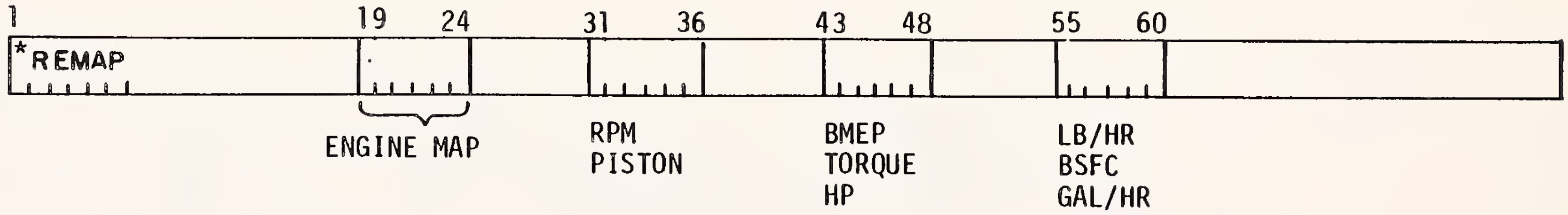
Units: AREA (sq. ft.)
DISPLACEMENT (cu in)
FUEL DENSITY (sp gr)
STROKE (in)
TIRE EFF (1. max)
WEIGHT (lbs)
WIND (mph)
IDLE (RPM)
STEP (sec) - default is .05 sec
UPSHIFT (± % change in vac/throt)
DOWNSHIFT (± % change in vac/throt)
PHI (Radians)
C_1, C_2

Enter Value with decimal point
(Note: Must specify accessory to be modified



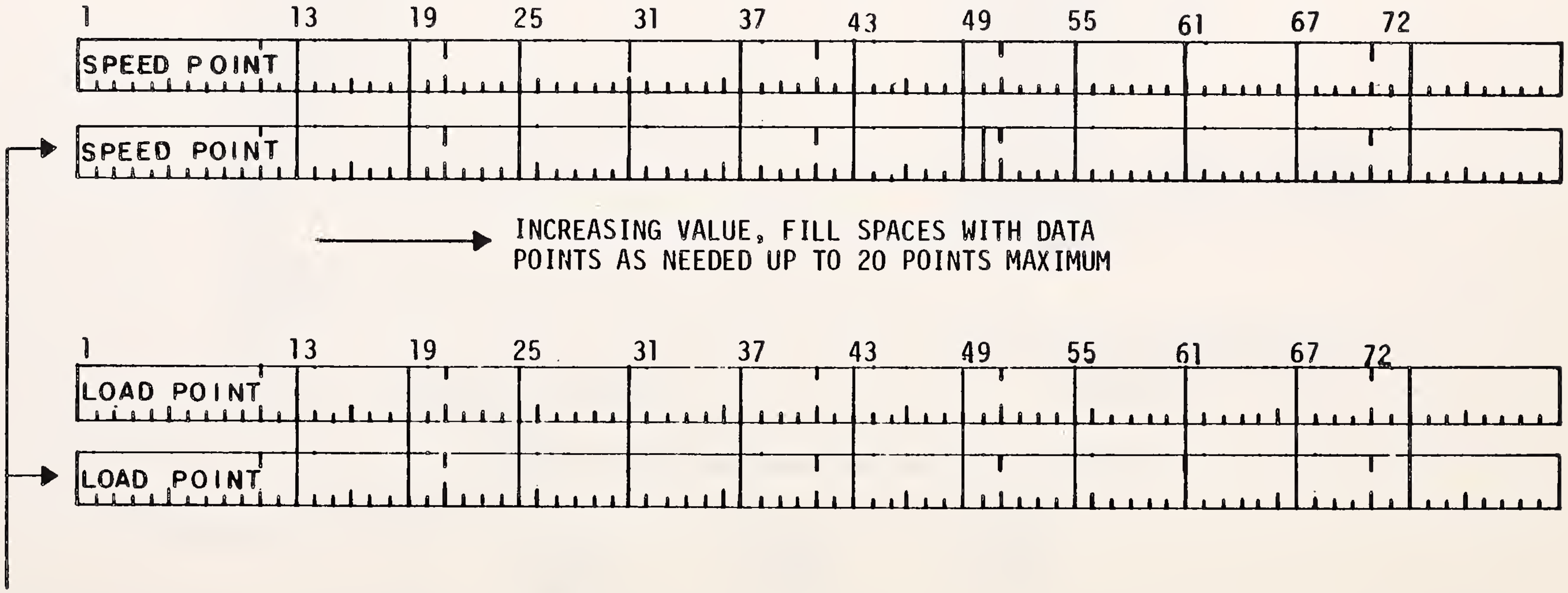
(enter one of the above for each set of units)

DATA SHEET 21. REMAP



(enter one of the above for each set of units)

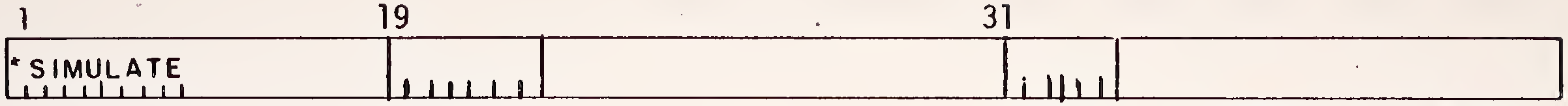
NOTE: ENTER ALL DATA WITH A DECIMAL POINT



INCREASING VALUE, FILL SPACES WITH DATA POINTS AS NEEDED UP TO 20 POINTS MAXIMUM

USE ONLY
WHEN MORE
THAN 10
DATA POINTS
TO BE ENTERED
FOR EACH

DATA SHEET 22. SIMULATE

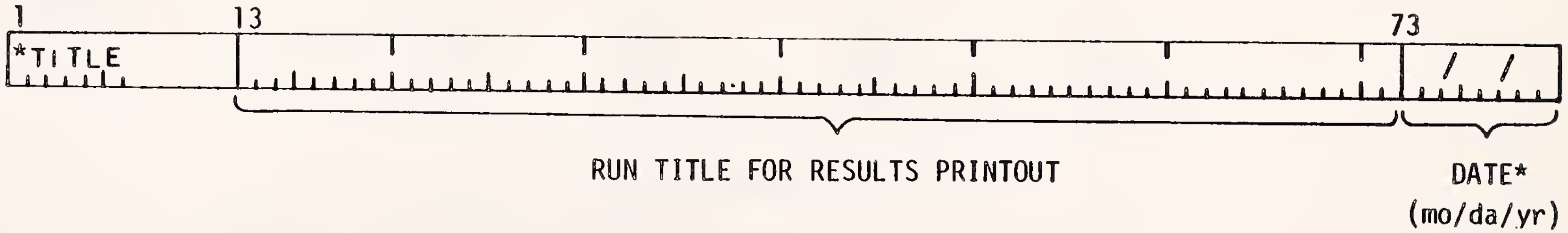


BLANK
CAR

(Default, Car)

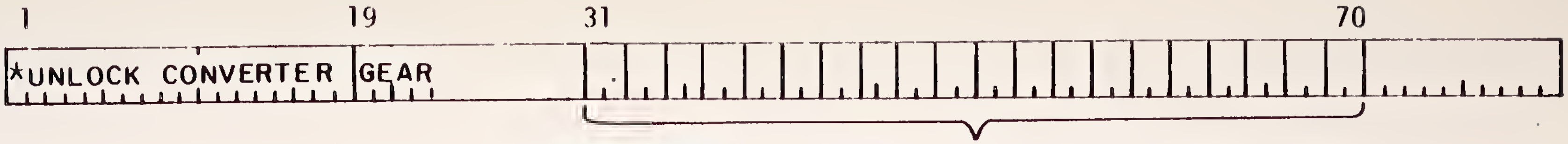
DIALOG - IF UNDER USER CONTROL,
BATCH GO TO COMMAND LEVEL
CONTI BEFORE SIMULATING

DATA SHEET 23. TITLE



*Optional - insert to override actual date

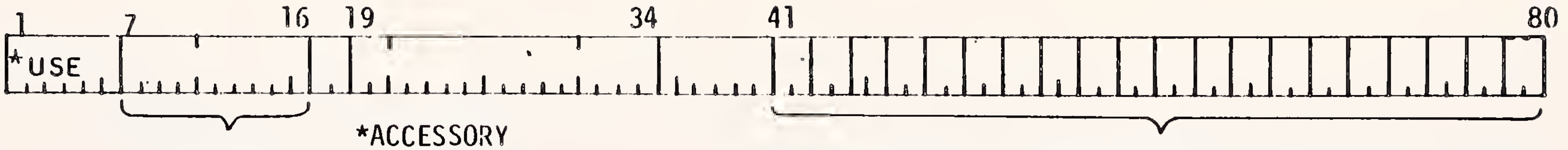
DATA SHEET 24. UNLOCK CONVERTER GEAR



LIST GEAR NUMBERS WITHOUT DECIMAL POINTS (right justify)

NOTE: GEAR NUMBERS RANGE FROM 1 TO 20

DATA SHEET 25. USE



PART NAME

*ACCESSORY
*CONVERTER

*DRIVING SCHEDULE
*ENGINE - LIST ALL GEARS TO BE USED WITH THE ENGINE
*GEAR - SPECIFY THE GEAR
*ROUTE
*SHIFT LOGIC
*VEHICLE

LIST GEAR NUMBERS WHEN REQUIRED WITHOUT DECIMAL POINTS (right justified), gear numbers range from 1 to 20

(enter one of the above)

NOTE: ONE OF EACH PART ABOVE MUST BE DEFINED BY A USE COMMAND IN ORDER TO RUN A SIMULATION WITH THE FOLLOWING EXPECTIONS:

1. ACCESSORIES ARE NOT REQUIRED.
2. TWO CONVERTERS (drive and coast) must be specified.

*More than one of these parts may be defined.

DATA SHEET 26. ZERO

```
1
*ZERO
```

<u>NOTE</u>: THIS COMMAND RESETS THE ENTIRE PROGRAM TO ITS' INITIAL STATE AND ERASES ALL PARTS LOADED WITH THE USE COMMAND

TABLE SHEET 27. SPLIT

```
*SPLIT
```

<u>NOTE</u>: THIS COMMAND EXECUTES THE SPLIT TORQUE OPTION

6. GRAPHIC OPTIONS

The graphics package was designed with the intent to enhance capabilities of the VEHSIM program. This is a powerful tool which helps the user to visualize input and output data. It is a user-oriented package in the sense that it was designed to minimize the involvement of the user in the execution of the programs. The listing of the programs (See Vol III) contains commentary and extensive flow diagrams were produced for the entire package. The user is given a choice of running the program via the TEXTRONIX terminal or of writing it on tape and producing results on the CALCOMP plotter.

6.1 DESCRIPTION OF PROGRAM SURF3D.FOR

Program SURF3D.FOR was designed to produce an image of 3-D surfaces. Mathematically, a surface is defined to be some function of two variables, X and Y, which can vary independently of one another. The function value is represented on the Z coordinate axis.

In order to represent a surface with a device that can only draw lines, it is usually necessary to project a succession of lines lying on the surface. The manner in which the lines may be chosen is arbitrary, but the method used most often is to drop a rectangular mesh, or grid, over the surface and represent the surface in terms of the deformation of this tight fitting "stocking." This is the technique used by this program and it may be stated formally by saying that the surface is represented in terms of lines having

a) constant X and varying Y and Z
b) constant Y and varying X and Z.

The projection of this mesh onto the X-Y plane is a grid and is referred to as the base grid of the surface. Program SURF3D.FOR constructs a surface from scattered (non-regular X-Y) points. It constructs a regular Z matrix from the scattered (X, Y, Z,) values regardless of their X and Y ordering. It can be noted that the program will also produce results for the surfaces defined by the matrix, or array, whose values correspond to the Z values at the intersection (mesh points) of the base grid. The user is given a choice of running the program interactively via TEXTRONIX terminal or writing it on tape with the following drawing on CALCOMP plotter. The program asks the user to type the numbers NX and NY which stand for the number of rows and columns in the matrix. If the data are scattered (non-regular) one still has to tell the computer what kind of X-Y matrix he expects to get. The default value for NX is 20 and for NY is 10. The data input for the program is normally very large. This is why the input data must be stored in the file VAS.DAT on disk B. An example of file VAS.DAT is shown in Table 6-1 and an example of output is shown in Figures 6-1 and 6-2. This program is closely related to the program SURF2D.FOR. These two programs represent two alternative ways of showing the 3-D surface. The listing of the program contains comments.

6.2 DESCRIPTION OF PROGRAM SURF2D.FOR

Program SURF2D.FOR was designed to produce an image of contour plots of a user's data. The contouring enables the user to display a surface representing a function of two variables. One method of displaying this surface is through 3-D representation (see description of program SURF3D.FOR). Another way is by slicing the surface horizontally and drawing the lines of intersection with the surface. These are called contour lines.

Once a surface is described in matrix form, a set of contour lines may be generated. The technique for generating contour lines is a linear interpolation of adjacent surface grid points in both the X and Y directions. The user is given a choice of running the program interactively via the TEXTRONIX terminal or of writing it on tape with the following drawing on the CALCOMP plotter. The user is asked to type the numbers NX and NY which stand for the number of rows and columns in the X-Y matrix. If the input

TABLE 6-1. ARRAY OF FIVE DIMENSIONAL VECTORS

RPM	T	$\dot{m}$	α	VAC
550.00	0.00	3.00	0.00	14.50
550.00	31.90	3.00	0.00	14.50
550.00	32.10	3.00	0.00	14.50
550.00	32.20	3.00	0.00	14.50
550.00	32.40	3.10	0.00	14.50
550.00	32.60	3.10	0.00	14.50
550.00	32.80	3.10	0.00	14.50
550.00	32.90	3.10	0.00	14.50
550.00	33.10	3.10	0.00	14.50
550.00	33.30	3.10	0.00	14.60
550.00	33.50	3.10	0.00	14.60
550.00	33.60	3.10	0.00	14.70
550.00	33.80	3.10	0.00	14.70
550.00	34.00	3.20	0.00	14.80
550.00	34.20	3.20	0.00	14.90
550.00	34.30	3.20	0.00	15.00
550.00	34.50	3.20	0.00	15.10
550.00	34.70	3.20	0.00	15.30
550.00	34.90	3.20	0.00	15.40
550.00	35.00	3.20	0.00	15.50
800.00	-6.80	3.00	0.00	18.50
800.00	1.20	3.30	0.00	18.50
800.00	2.00	3.00	0.00	17.00
800.00	2.70	3.00	0.00	17.00
800.00	3.50	3.00	0.00	17.00
800.00	4.30	3.00	0.00	17.00
800.00	5.00	3.00	0.00	17.00
800.00	5.80	3.00	0.00	17.00
800.00	6.60	3.00	0.00	17.00
800.00	7.30	3.00	0.00	17.00
800.00	8.10	3.00	0.00	17.00
800.00	8.90	3.00	0.00	17.00
800.00	9.60	3.00	0.00	17.30
800.00	10.40	3.70	0.00	17.90
800.00	11.20	3.70	0.00	17.00
800.00	11.90	3.70	0.00	17.00
800.00	12.70	3.70	0.00	17.00
800.00	13.50	3.50	0.00	17.00
800.00	14.30	3.00	0.00	17.00
800.00	193.90	17.60	80.00	0.10
1000.00	-12.30	3.00	2.00	18.50
1000.00	0.90	4.00	2.00	18.50
1000.00	13.50	4.00	2.40	17.70
1000.00	26.00	4.40	3.10	17.10
1000.00	38.60	5.10	4.10	16.20
1000.00	51.10	5.90	5.30	15.00
1000.00	63.70	6.90	6.70	13.40
1000.00	76.20	8.10	8.30	11.50
1000.00	88.80	9.20	10.10	9.40
1000.00	101.30	10.40	12.30	7.10
1000.00	113.90	11.50	14.70	5.00
1000.00	126.50	12.70	17.30	3.10
1000.00	139.00	13.80	19.90	1.60
1000.00	151.60	14.80	21.90	0.70
1000.00	164.10	15.80	23.00	0.30
1000.00	176.70	16.80	23.20	0.40
1000.00	189.20	17.80	23.60	0.80
1000.00	201.80	18.80	26.10	1.20
1000.00	214.30	19.80	36.50	1.10
1000.00	226.90	21.00	80.00	0.10

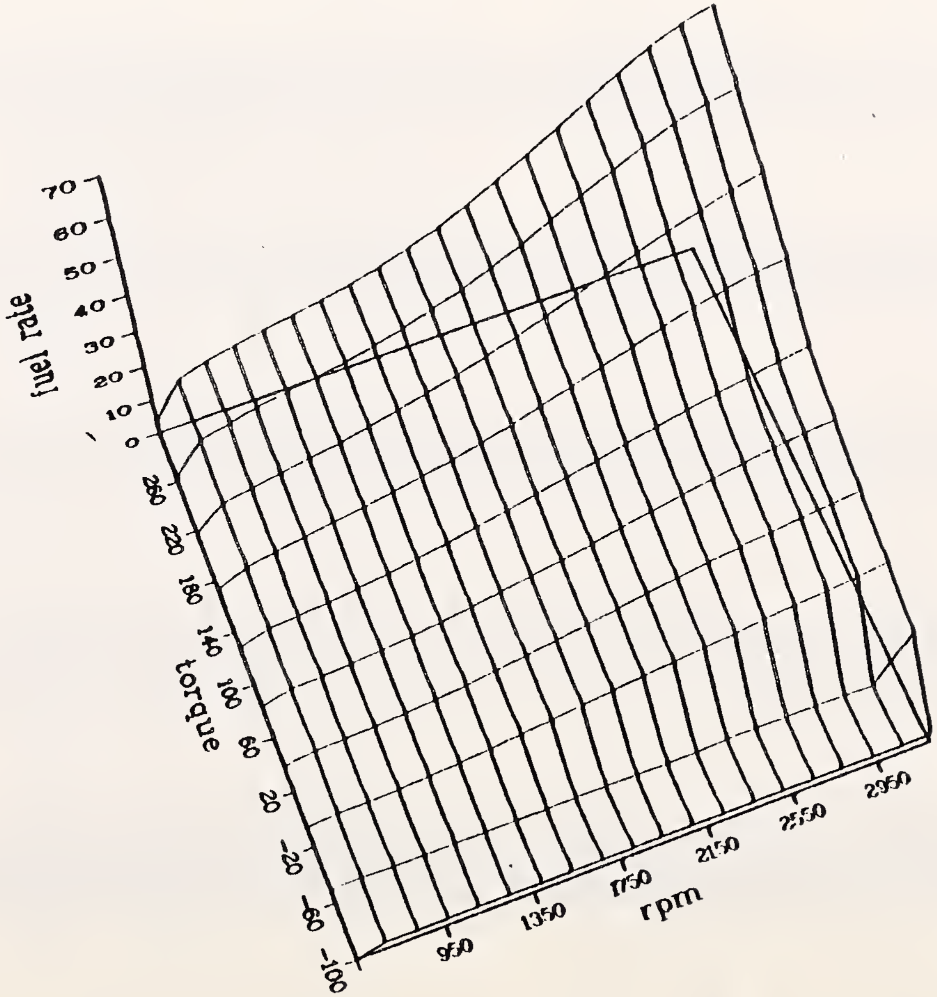


FIGURE 6-1. ENGINE FUEL MAP FOR 5.9ℓ ENGINE

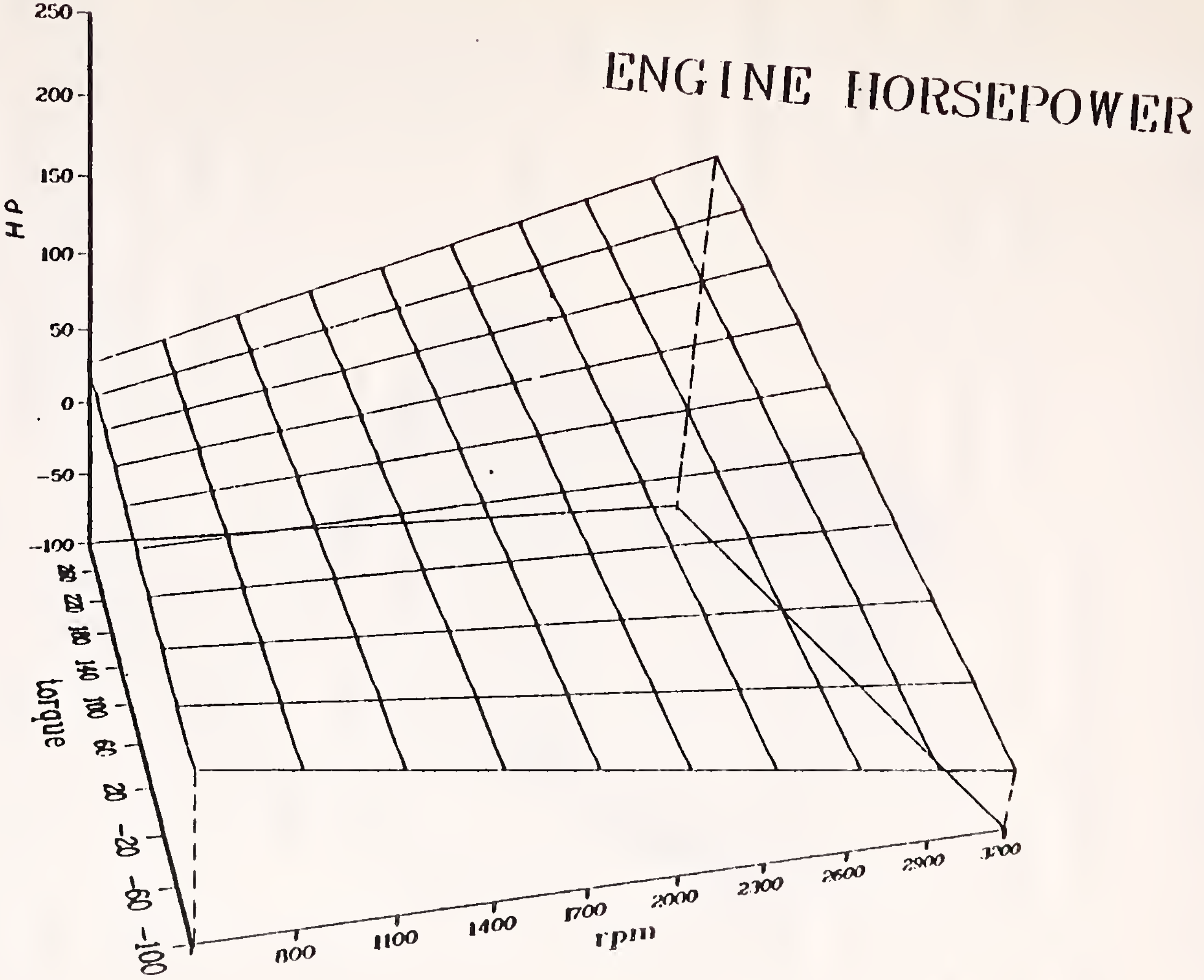


FIGURE 6-2. HORSEPOWER AS A FUNCTION OF ENGINE TORQUE AND RPM

data are scattered, or non-regular, the user must identify the kind of matrix (periodicity) desired. The input data for SURF2D.FOR is normally very large. This is why the input data must be stored in file VAS.DAT on disk B. The listing of the program contains comments. An example of input data is shown in Table 6-1. Examples of output are shown in Figures 6-3 and 6-4.

6.3 DESCRIPTION OF PROGRAM GEO.FOR

Program GEO.FOR was designed to produce contour plots of a user's data on a 2-D surface. The contouring enables the user to display a surface representing a function of two variables. One method of displaying this surface is through 3-D representation (see description of program SURF3D.FOR). Another way is by slicing the surface horizontally and drawing the lines of intersection with the surface. These are called contour (or geodesic, or equipotential) lines.

Program GEO.FOR draws the contour lines on a 2-D axis system. GEO.FOR is closely related to the program SURF2D.FOR. SURF2D.FOR draws the contour lines on a 3-D axis system. Program GEO.FOR is quite general and may be applied to all sorts of applications. Once a surface is described in matrix form, a set of contour lines may be generated. The technique GEO.FOR uses for generating contour lines is a linear interpolation of adjacent surface grid points in both X and Y directions. It does not interpolate or smooth data values and it works on a regular set of data.

Contour line drawings differ from normal curve drawings in that each set of curves represents a different vertical level of the data. Having all of these lines drawn as the same type of curve would make it nearly impossible to read a contour plot. Therefore, GEO.FOR will draw the more significant levels as heavy (bolder) lines. They will be labeled with the value of the Z level.

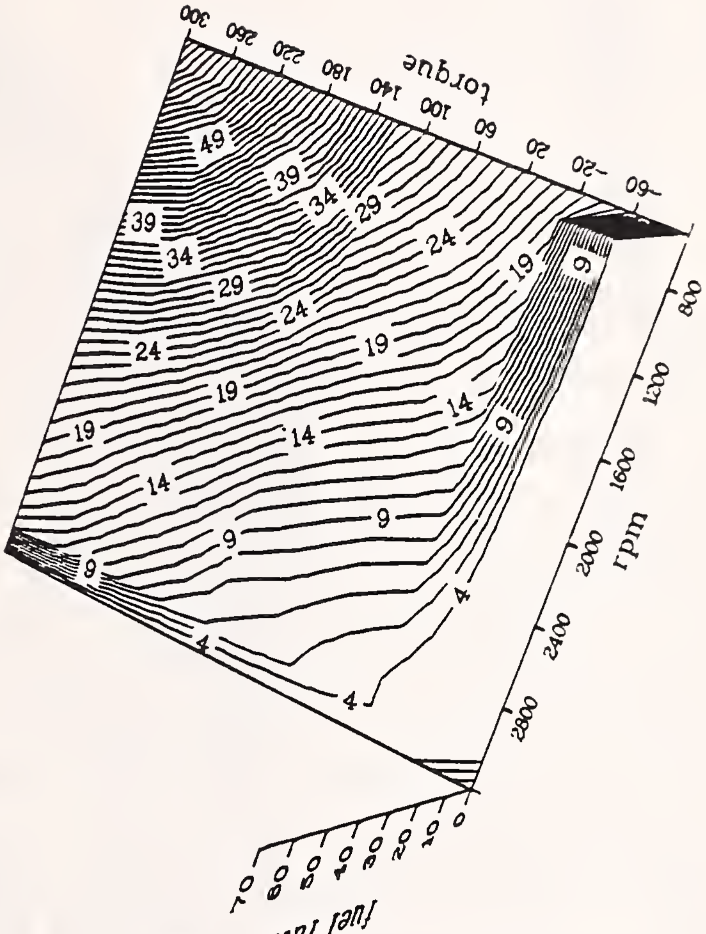


FIGURE 6-3. ENGINE FUEL MAP CONTOUR PLOT

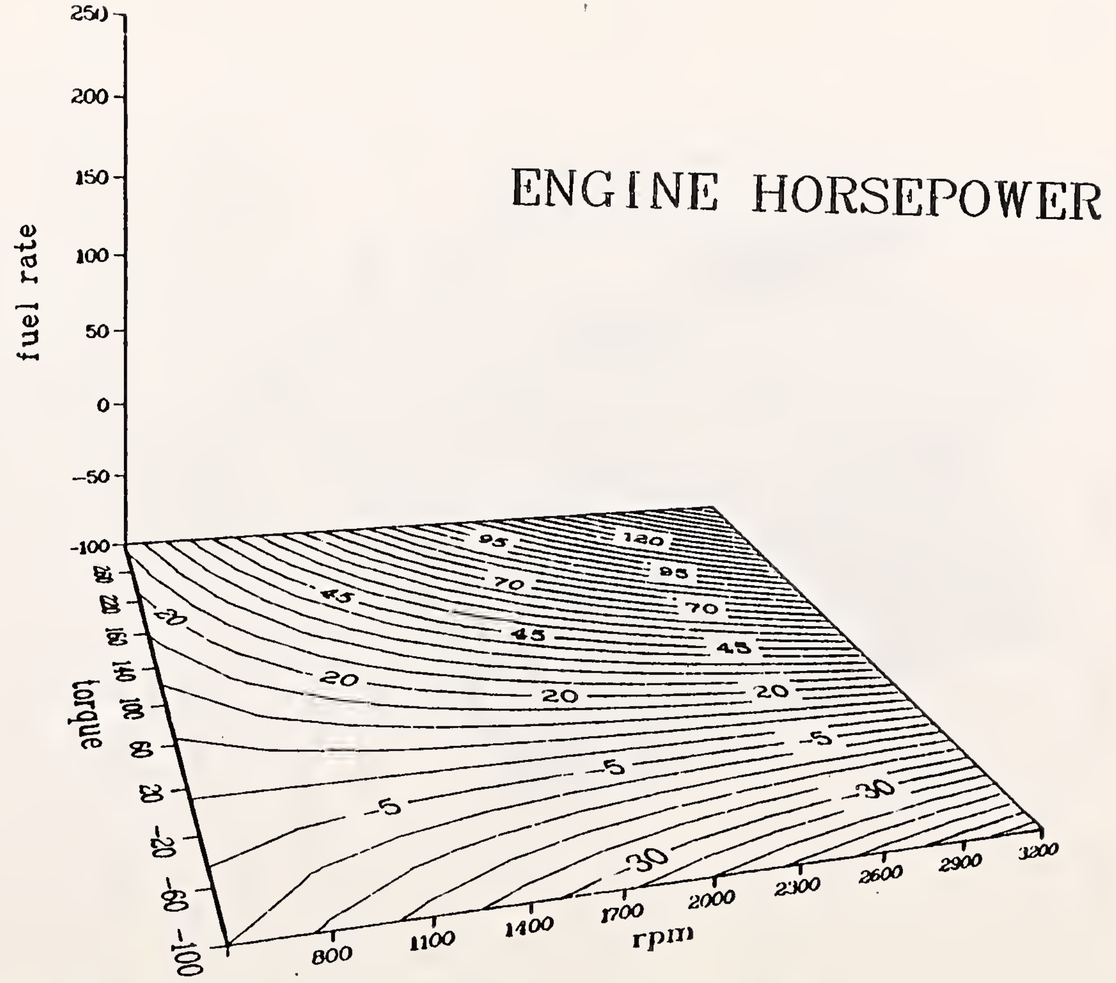


FIGURE 6-4. ENGINE HORSEPOWER AS A FUNCTION OF TORQUE AND RPM

The user is given a choice of running the program interactively via TEXTRONIX terminal or of writing it on tape with the following drawing on CALCOMP plotter. The user is asked to type the numbers NX and NY which stand for the number of rows and columns in the X-Y matrix. The default value for NX is 20 and for NY it is 10. The user already has a two dimensional array, Z, on file 'VAS1.DAT' on disk B. GEO.FOR will scan the Z array and generate **contour-line** curves at intervals of every 5 units. The program will ask the user to type the number of rows and columns in the matrix. The listing of the program contains comments. An example of input data is shown in Table 6-1. Examples of output data are shown in Figure 6-5.

6.4 DESCRIPTION OF PROGRAM HPOWER.FOR

Program HPOWER.FOR was designed with the intent of drawing the family of curves which are described by the same algorithm.

In this program, the horsepower of the engine is calcculated as a function of torque and RPM. In a 3-D space. this would correspond to a family of parabolic hyperboloids. This program does the 2-D representation of horsepower as a function of torque and RPM. As a result of the execution of HPOWER.FOR, one gets a family of hyperbolas which represent horsepowers with the user-supplied increment (in H.P.). The resulting curves are distinguished by different marks. There are 15 different markers and they are repeated only when all of them are exhausted.

The program asks the user to type the number NN which stands for the number of curves to be drawn. It also asks for the increment INCR which stands for the step increment between two curves. The user is given a choice of running the program via TEXTRONIX terminal or using CALCOMP plotter. The listing of the program contains comments. An example of output is shown in Figure 6-6.

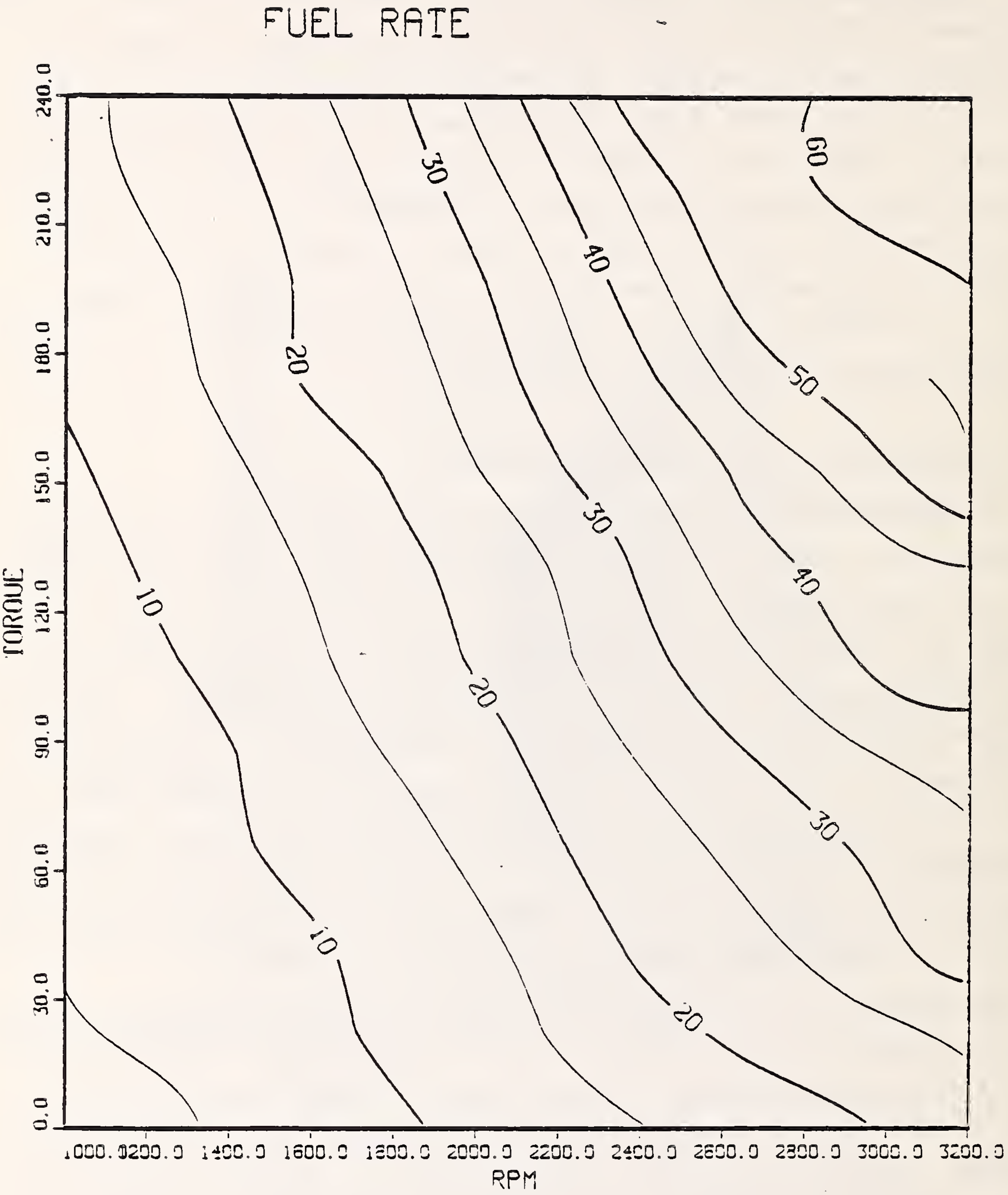


FIGURE 6-5. ENGINE FUEL MAP CONTOUR PLOT

6.5 DESCRIPTION OF PROGRAM DIABGR.FOR

Program DIABGR.FOR was designed with the intent of plotting the data on a two dimensional axis system. It draws all the inputted points and supplies them with a distinguishing mark. Additionally, the program draws the grid.

The user is given a choice of running the program interactively via TEXTRONIX terminal or writing it on the tape with the following drawing on CALCOMP plotter. The user is asked to enter the number IM which stands for marker specification:

+1 - points are connected and there is a symbol at every point;
-1 - points are not connected and there is a symbol at every point;
0 - points are connected with no symbols drawn.

A symbol will always appear at the first and last points of IM.NE.0 regardless of the value of IM. The default value of IM is +1. The listing of the program contains comments. An example of the program output is shown in Figure 6-7.

6.6 DESCRIPTION OF PROGRAM TRANSF.FOR

Program TRANSF.FOR was designed for the transformation of output data from the VEHSIM program to a form suitable for use as input data for a wide variety of graphics programs. It should be noted that the philosophy of this program is very general and is applicable to a wide class of transformation problems. This program transforms the VEHSIM output data onto an array of five dimensional vectors. TRANSF.FOR calls subroutine MB0001.FOR. As an example, consider an output "ENGINE DATA" (see Table 6-2). The program will transform the engine data onto an array of vectors where column 1 represents speed (RPM), column 2, torque (ft-lb), column 3, fuel rate (lb/hr), column 4, throttle (degrees), and column 5, manifold vacuum (in. of Hg) (see Table 6-1). It has been shown that with this type of formatted data it is very easy to automate the input for a wide range of programs. As an input for TRANS.FOR, use file "MB0001.DAT" sorted on disk B (see Table 6-1). Output will have the name 'VAS.DAT' and will also be stored on disk B. The listing of the program contains comments.

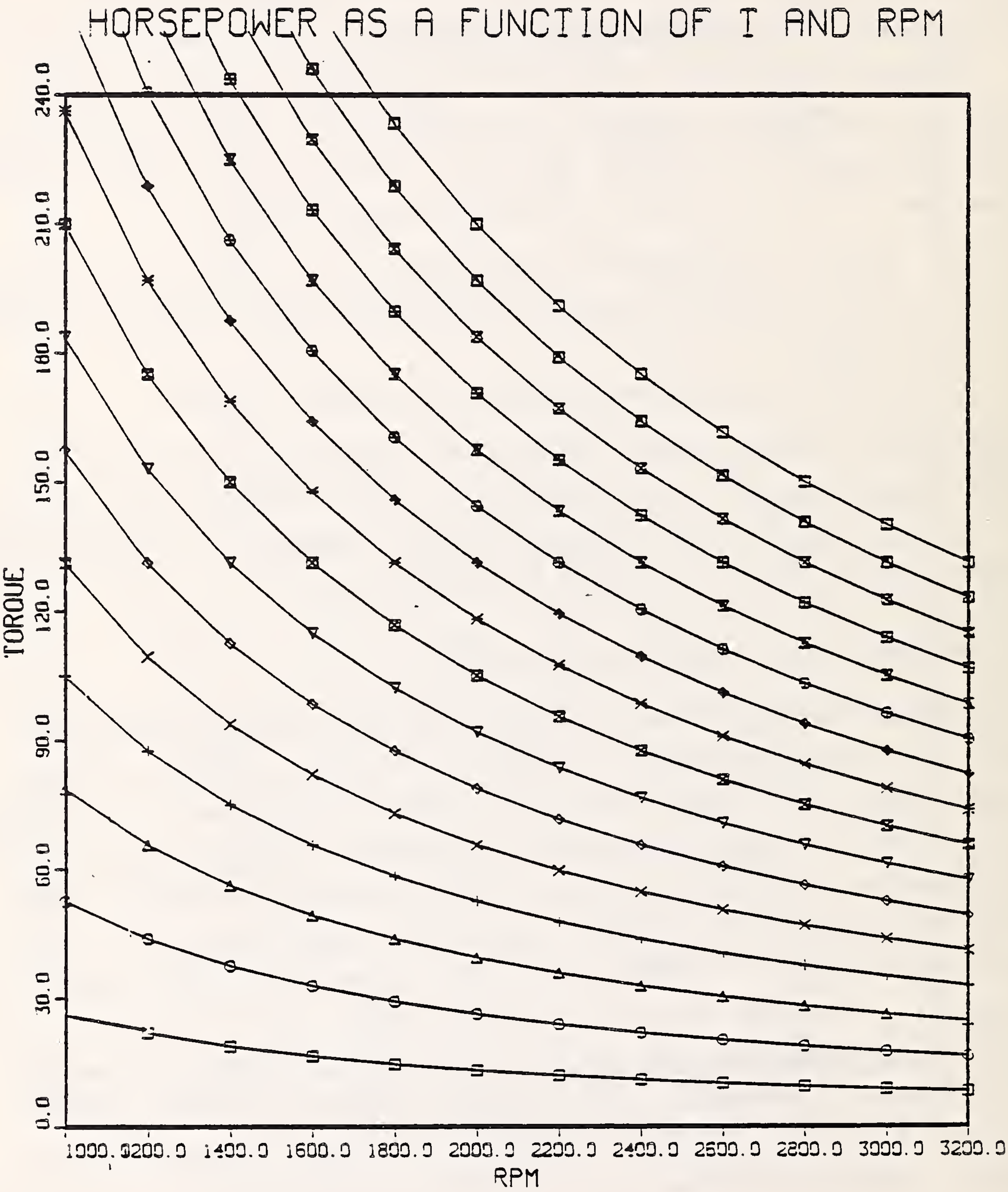


FIGURE 6-6. FAMILY OF HORSEPOWER CURVES

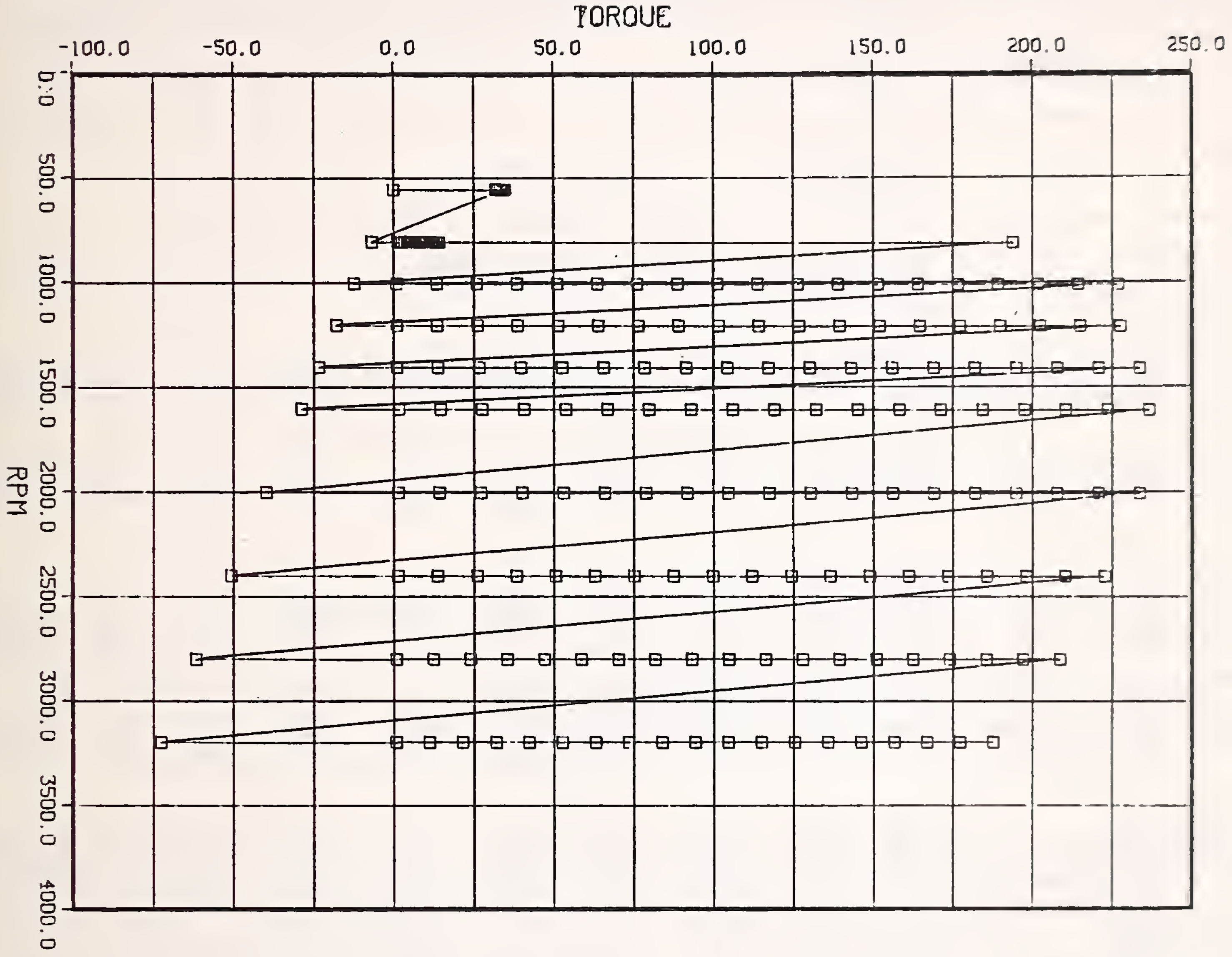


FIGURE 6-7. ENGINE MAP DATA POINTS

TABLE 6-2. ENGINE DATA FROM VEHSIM DATA BASE

```
 VSMCAR CAR    06(23) 16-OCT-80    14:12 JOB# 37 TTY071  DSKB  :[04132,402]
1 ENGIN PARTS DATA FILE DIRECTORY 16-OCT-80   DSKB  :VSMENG.BIN[04132,402]
 -------------------------------------------------------------------------

1 16-OCT-80
+                    ENGINE DATA  ( F8FJLO.114 )
                     ---------------------------

   1978       300.0 ENGINE FUEL MAP       CATALYTIC CONVERTER

  CYLINDERS     =     6           FUEL DENSITY       =    5.976  LB/GAL
  BORE          =     4.000       ROTATING INERTIA   =    0.100  FT-LB-SEC**2
  STROKE        =     3.980
  DISPLACEMENT  =   300.1                         MINIMUM    MAXIMUM

  10 SPEED POINTS                 THROTTLE ANGLE   =     0.00       80.00   DEGREES
                                  ENGINE SPEED     =   800.0      3200.0    RPM
  SPEED (RPM) =   550.00
  --------------------
      TORQUE(FT-LB)                   0.00    31.90    32.10    32.20    32.40    32.60    32.80    32.90    33.10    33.30
      FUEL RATE(LB/HR)                3.00     3.00     3.00     3.00     3.10     3.10     3.10     3.10     3.10     3.10
      THROTTLE(DEGREES)               0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
      MANIFOLD VACUUM(IN-HG)         14.50    14.50    14.50    14.50    14.50    14.50    14.50    14.50    14.50    14.60

      TORQUE(FT-LB)                  33.50    33.60    33.80    34.00    34.20    34.30    34.50    34.70    34.90    35.00
      FUEL RATE(LB/HR)                3.10     3.10     3.10     3.20     3.20     3.20     3.20     3.20     3.20     3.20
      THROTTLE(DEGREES)               0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
      MANIFOLD VACUUM(IN-HG)         14.60    14.70    14.70    14.80    14.90    15.00    15.10    15.30    15.40    15.50

  SPEED (RPM) =   800.00
  --------------------
      TORQUE(FT-LB)                  -6.80     1.20     2.00     2.70     3.50     4.30     5.00     5.80     6.60     7.30
      FUEL RATE(LB/HR)                3.00     3.30     3.00     3.00     3.00     3.00     3.00     3.00     3.00     3.00
      THROTTLE(DEGREES)               0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
      MANIFOLD VACUUM(IN-HG)         18.50    18.50    17.00    17.00    17.00    17.00    17.00    17.00    17.00    17.00

      TORQUE(FT-LB)                   8.10     8.90     9.60    10.40    11.20    11.90    12.70    13.50    14.30   193.90
      FUEL RATE(LB/HR)                3.00     3.00     3.00     3.70     3.70     3.70     3.70     3.50     3.00    17.60
      THROTTLE(DEGREES)               0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00    80.00
      MANIFOLD VACUUM(IN-HG)         17.00    17.00    17.30    17.90    17.00    17.00    17.00    17.00    17.00     0.10

  SPEED (RPM) =  1000.00
  --------------------
      TORQUE(FT-LB)                 -12.30     0.90    13.50    26.00    38.60    51.10    63.70    76.20    88.80   101.30
      FUEL RATE(LB/HR)                3.00     4.00     4.00     4.40     5.10     5.90     6.90     8.10     9.20    10.40
      THROTTLE(DEGREES)               2.00     2.00     2.40     3.10     4.10     5.30     6.70     8.30    10.10    12.30
      MANIFOLD VACUUM(IN-HG)         18.50    18.50    17.70    17.10    16.20    15.00    13.40    11.50     9.40     7.10

      TORQUE(FT-LB)                 113.90   126.50   139.00   151.60   164.10   176.70   189.20   201.80   214.30   226.90
      FUEL RATE(LB/HR)               11.50    12.70    13.80    14.80    15.80    16.80    17.80    18.80    19.80    21.00
      THROTTLE(DEGREES)              14.70    17.30    19.90    21.90    23.00    23.20    23.60    26.10    36.50    80.00
      MANIFOLD VACUUM(IN-HG)          5.00     3.10     1.60     0.70     0.30     0.40     0.80     1.20     1.10     0.10

  SPEED (RPM) =  1200.00
  --------------------
      TORQUE(FT-LB)                 -17.80     1.00    13.60    26.20    38.80    51.40    64.00    76.50    89.10   101.70
      FUEL RATE(LB/HR)                3.00     4.70     4.80     5.30     6.00     6.90     8.00     9.30    10.70    12.10
      THROTTLE(DEGREES)               3.20     3.20     3.90     4.80     5.80     6.90     8.30    10.00    12.00    14.50
      MANIFOLD VACUUM(IN-HG)         18.50    18.50    18.00    17.40    16.50    15.20    13.60    11.60     9.40     7.10

      TORQUE(FT-LB)                 114.30   126.90   139.50   152.10   164.70   177.30   189.90   202.50   215.00   227.60
```

7. COMMON ERRORS

Beginning users of VEHSIM tend to make the same errors. A compilation of these errors was made based on user inquires to TSC's Energy Technology Branch. An understanding of each of the errors (including proper interpretation of results) listed below will reduce the fustrations normally experienced by the novice user.

1. Distinction between lockup and non-lockup of gears.
2. Are tires included in the vehicle part or are tires separate part?
3. Shift logic for EPA Highway or Urban Drive Schedules for manual transmission will always be:
   - o EPA3 → Manual 3 speed
   - o EPA4 → Manual 4 speed
   - o EPA5 → Manual 5 speed
4. Shift logic for automatic transmission is NOT EPA3, EPA4, or EPA5, but fixed by the manufacturer. One example is T3R2 for 3 speed automatic.
5. Performance drive schedules (e.g. 0-60 wide open throttle) require different shift logic than that for fuel economy. The particular shift logic is based on the engine. Some examples include

3 WOT3800,	3 WOT3600
3 gears	3 gears
shift at 3800 RPM	shift at 3600 RPM

6. Distinction among C_1, C_2, and C_D and relative magnitude of their values.
7. Definition of "shift stutter" and where to look for solution to this problem:

   A. On second by second printout, look at gear number

   B. Shift frequency summary

8. Understanding of output variables and their units

Running output:

- Acceleration
- Horsepower at wheels
- Engine RPM
- Engine torque
- Road load horsepower
- Gear number
- Brake specific fuel
- Transmission efficiency
- Speed ratio
- Torque ratio
- Brakes
- Gradeability

Summary output:

- Fuel economy
- Time, fuel distribution
- Energy summary
- Shift frequency
- Gear time distribution
- Engine histogram
  - Time
  - Torque/speed
  - Horsepower

9. Be capable of modifying or creating new parts that include:

- Engine
- Converter
- Transmission
- Gear
- Vehicle
- Tires
- Route
- Drive schedule
- Accessory

This should be accomplished interactively for quick reaction situations that require minor modifications. Major changes will be accomplished by submitting cards via batch mode, such as for a long drive schedule.

10. Be capable of obtaining a listing of:
    - program
    - parts directory
        - Entire directory and parts list
        - Any particular part
11. Eventually familarize yourself with program algorithm and, in particular, with output sequence as minor changes in program output will be periodically required.

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